UNITED STATES DEPARTMENT OF AGRICULTURE

Miscellaneous Publication No. 273

Washington, D. C.

Issued February 1938
Revised July 1952

INSECT ENEMIES OF WESTERN FORESTS

By

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Entomologist
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UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1952

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price $1 (paper cover)

PREFACE

This field manual has been prepared to meet the needs of forest rangers, field men, and others entrusted with the protection of forest resources, the prevention of insect damage to timber crops, and the control of forest-insect outbreaks. All sources of information have been drawn upon to make the compilation as comprehensive and up-to-date as possible.

Published bulletins, articles, and records, unpublished reports by field men, and manuals of instruction have been used freely as needed. The text of earlier editions has been revised extensively, to take into account the new insecticides developed during World War II and the tremendous change such chemicals as DDT have made on forest-insect-control procedures. J. M. Miller, J. C. Evenden, R. L. Furniss, and N. D. Wygant furnished material from the different regions of the West. In fact, the entire technical force of the Bureau's western forest-insect laboratories contributed material for this publication. J. E. Patterson assisted in preparing the illustrations.

This manual is restricted to insects found in forests west of the Great Plains, roughly the 100th meridian. Insects of shade and ornamental trees are touched upon only incidentally. A companion volume, "Insect Enemies of Eastern Forests," by F. C. Craighead and eastern workers (*37*) (Miscellaneous Publication 657) should be consulted for information on eastern forest insects and many others that are Nation-wide in distribution.

CONTENTS

INSECT ENEMIES OF WESTERN FORESTS

By F. P. Keen, *entomologist, Division of Forest Insect Investigations, Bureau of Entomology and Plant Quarantine, Agricultural Research Administration*

The protection of forests from destruction is the first requirement in the practice of forestry. Insect pests rank high among the important destructive agents. Although the damage they cause is less spectacular than that done by fire or wind, it may result in great losses of timber. Insects are constantly at work in the forest and cause a steady drain on timber supplies. To allow them to run unchecked through our forests is to invite disaster and threaten present and future supplies of timber.

Injurious insects may be encountered in every forest operation, from the collection of seed through the planting, growing, and harvesting of the trees, in the handling and protection of wood products, and even in the management of grazing lands. It is hoped that the information assembled in this handbook will aid timber owners and foresters in recognizing the work of important western forest insects, in applying suitable control measures, or in adjusting forest practices so as to reduce losses from this source to the lowest possible point.

KINDS OF FOREST INSECTS AND THE LOSSES THEY CAUSE

All forests are swarming with insect life. This insect population serves many functions and is as much an essential part of the complex association of living, growing, and dying organisms which we call the forest as are the trees themselves.

Of the thousands of insect species found within our forests, many are harmless, or even beneficial. A great many feed on dead trees and on fallen limbs and other debris upon the forest floor, and thus hasten the disintegration of dead material and make room for new growth. Many others prey upon destructive insects and hold them in check.

A certain proportion of the insect species, however, are distinctly harmful, as they attack healthy or partially weakened trees and impair their vitality or even kill them. Of this group, bark beetles destroy more standing timber in our western forests than all other insects combined. Defoliators—insects that feed directly on the foliage—are the next greatest destroyers of standing timber. Other insects, such as weevils, tip moths, pitch moths, and cone beetles, attack various portions of the green trees, often with serious results. In spite of the large number of insect species that prey upon the forests, comparatively few cause damage of economic importance.

Injurious insects may be roughly classed as primary or secondary, depending on the health of the trees they normally attack.

Certain species, such as the leaf-chewing insects, show a decided preference for perfectly healthy trees and are considered primary in their attack. Others, such as most bark and wood-boring insects, can inhabit only trees previously weakened by some other agent.

In insect-control (fig. 1) work it is important to know whether a species is primary or secondary in its attack, as it is wasted effort to proceed against an insect if its presence is conditioned by previous injury or death of the tree from other causes. It is the

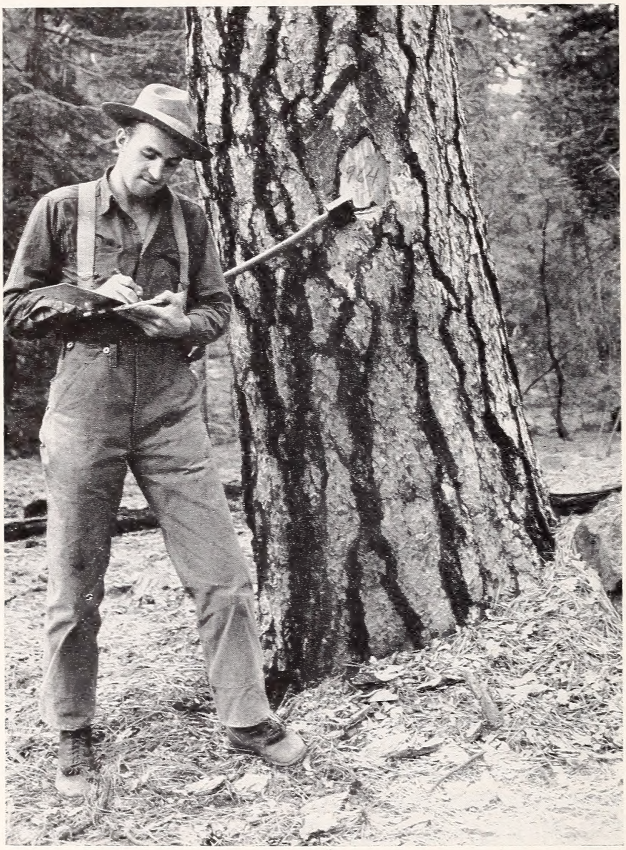

FIGURE 1.—Insect control is one of a forest ranger's many routine tasks. Marking an infested tree.

primary injury that must be discovered and dealt with. However, a number of species are primary under certain conditions and secondary under others.

Every kind of western forest tree has its insect enemies. Western yew is probably as nearly free from insect attack as any other forest tree in the West. An occasional scale or caterpillar may be found on its foliage and beetles occasionally enter its heartwood through wounds, especially if the wood is beginning to decay, but no serious enemy is known. The cedars, cypresses, redwood, and

junipers have very few injurious insect enemies and none that threaten the life of mature trees. Larch also is comparatively free from insect pests. The broadleaved trees are the favored hosts of many leaf-feeding species; but, since these trees can readily replace their depleted foliage, such feeding is rarely fatal. Some species, however, are much more subject to insect attack than others. Certain oaks are reported to be hosts for more than 1,000 species of insects. Pines, spruces, firs, and hemlocks suffer much, in the order named.

Injurious forest insects are constantly at work, taking toll at every stage in the development of the stand, and even after the tree has been converted into lumber. Some insects feed on the roots, others on the leaves, the terminal shoots, the branches, or the phloem and bark of the main trunk. Still others feed on the sapwood, and even on the heartwood. The fruits and the seeds also are subject to attack by many insect species.

In certain types of old-growth timber stands, particularly those that are overmature, steady loss through insect activity is normal, and this loss is for the most part counterbalanced by new growth. On the other hand, epidemic insect outbreaks from time to time definitely deplete the forest capital over large areas to such an extent that long periods are required for replacement (fig. 2). Annual loss caused by forest insects in the Western States, including depredations on standing timber and damage to logs, sawed lumber, and finished wood products in use, is variously estimated at 20 million to 100 million dollars.

Much of this loss is as unavoidable as losses from lightning or windstorms. On the other hand, much of it can be prevented through silvicultural practices, proper forest management, and direct control measures.

DIRECT LOSSES

In the mature timber stands of the West the largest single item of insect loss results from activities of bark beetles. Surveys indicate that these pests destroy annually 1 billion to 5 billion board feet of mature timber in our western forests.

A survey made in California in 1932 indicated that losses of merchantable timber due to bark beetles in that year totaled about 1,500 million board feet, which represents a loss of over 3 million dollars in stumpage values, aside from the regional asset represented by the manufacturing value of the lumber.

In eastern Oregon and Washington, during the 20-year period ending in 1940, the western pine beetle caused a gross loss of 15,480 million board feet of ponderosa pine (fig. 3). Typical high-hazard sections in this region showed from 35 to 50 percent net depletion in stand inventories. One area of the Modoc National Forest in California lost 78 percent of its merchantable timber from western pine beetle attack during this period.

The lodgepole pine forests of Idaho, Montana, and Wyoming, particularly those in and around Yellowstone National Park, have suffered tremendous losses from mountain pine beetle attack during the 30-year period following 1910. It has been conservatively

FIGURE 2.—Bark beetles, not fire, destroyed this stand of lodgepole pine in Yosemite National Park.

estimated that during the 10-year period ending in 1932 these losses amounted to 7,250 million board feet, more than 36 million trees having been killed in one national forest alone. Many mature lodgepole pine forests throughout the West have been virtually destroyed by this bark beetle since 1910, or are in the process of destruction. During the 10-year period 1923-32 the mountain pine beetle is also estimated to have destroyed 110 million board feet of valuable western white pine stands in northern Idaho and 1,280 million board feet of sugar pine in California.

An outbreak of the Engelmann spruce beetle between 1940 and 1950 is estimated to have killed 4,100 million board feet of Engelmann spruce in Colorado, representing about 20 percent of the total spruce in the State. On the White River Plateau in Colorado 95 percent of the merchantable spruce trees were killed.

It must be clearly understood that these loss estimates cover the normal, as well as the unusual drain on the forest. In the ponderosa pine type bark beetles kill a few trees every year. Normal losses on good sites of 20 to 40 board feet and on poor sites of

50 to 150 board feet per acre per year are typical. In lodgepole pine stands normal losses by bark beetles are practically negligible, so any marked losses indicate abnormal conditions.

Defoliating insects sometimes destroy extensive stands of mature timber. Major outbreaks, however, usually occur at rather long intervals and are nearly always of short duration. In western forests some of the worst defoliators are the pine butterfly, the

FIGURE 3.—A commercial ponderosa pine stand in California badly damaged by bark beetles.

Douglas-fir tussock moth, the spruce budworm, and the hemlock looper. In 1893–95 the pine butterfly practically wiped out the mature ponderosa pine stand on 140,000 acres of the Yakima Indian Reservation in Washington. Since then less severe outbreaks of this insect have occurred from time to time. In 1931–32 the Douglas-fir tussock moth destroyed a high percentage of the Douglas-fir stands on 300,000 acres of the Colville National Forest in northeastern Washington. Again in 1945 a serious outbreak developed on 410,000 acres of fir forests in Idaho and eastern Oregon and Washington. Along the coast of Oregon and north to Alaska the hemlock looper appears about every 10 years and completely destroys the western hemlock and associated trees over large areas. A disastrous outbreak took place in western Oregon and Washington in the years 1889 to 1891, followed by major outbreaks in 1919–21, 1929–32, and 1943–45. However, defoliators in general cause little widespread destruction.

Forest plantations are particularly subject to destructive insects, chiefly because a plantation is usually made up of a large planting of one kind of tree. Many plantations are established on soils not especially suitable for the tree species used, and the poor condition of the planting invites insect damage. Young trees and second-growth stands are often seriously damaged by insects that feed on the terminals. Bud and twig moths, tip weevils, and twig beetles not only damage and deform the terminal shoots but at times kill out seedlings, saplings, and poles over large areas. Pine plantations in the Nebraska sand hills have been badly set back by tip moths. Many areas of second-growth pine near logging operations have been swept by aggressive infestations of engraver beetles.

Rapid progress in the development of forest recreation has called attention to the destruction of trees especially valuable for recreational or aesthetic use. The importance of forest cover on national parks, game preserves, and other recreational areas cannot be estimated in board-feet values. Insect depredations which mar the beauty or destroy the protective value of the forest cover on park and other recreational areas justify higher expenditures for control work than might be considered reasonable on a commercial stand.

Injuries to the wood of living trees greatly reduce the value of lumber. Furthermore, all kinds of forest products, from the time the tree is felled and for many years after the wood is put into use, are subject to destruction by insects. Losses in green sawlogs and storm-felled timber, green-sawed and seasoned lumber, rustic construction, poles, posts, cross ties, and all manner of finished products are particularly heavy, since they include cost of manufacture or replacement, or both. Losses of this class are estimated at 0.5 to 5 percent of the total value of various classes of finished products.

INDIRECT LOSSES

Besides direct damage through destruction of trees and forest products, forest insects cause important indirect losses in reducing

forest growth and altering the stand from valuable to inferior kinds of trees.

In some forest types insects often are one of the chief limiting factors in successful management. They frequently upset well-organized plans aimed at the continuous production of forest crops. In the western white pine and lodgepole pine forests of the northern Rocky Mountain region bark beetles so affect the proportion of tree species as to convert many stands to entirely different composition. In Modoc County, Calif., a bark-beetle epidemic in a mixed second-growth stand of ponderosa pine and white fir killed out all the pine and converted the stand into pure fir.

Much less frequently the effect of insect activity on stand composition is beneficial. In the Yosemite and Crater Lake National Parks, for instance, lodgepole pine stands completely destroyed by bark beetles have been succeeded by stands of the hemlock-fir type, which, for park purposes at least, is far superior to the lodgepole pine type.

Certain defoliators, even though they do not kill the timber, may cause a cessation or reduction of growth, which may increase the rotation period of the stand by 5 to 10 or more years, or they may so weaken the trees as to make them easy prey for tree-killing bark beetles. Such defoliation may be local and confined to a single tree species, or may spread over an enormous area and involve several species. For instance, an outbreak of the pandora moth in the ponderosa pine stands of southern Oregon, between 1918 and 1925, covered approximately 400,000 acres. Growth measurements on plots on this area showed that over a period of 11 years the normal forest increment was reduced by an average of 32 percent, or approximately 100,000,000 board feet. The weakening of these trees was followed by heavy bark-beetle killing, as much as 30 percent of some stands having been killed by the beetles.

The spruce budworm, which is so destructive in the Northeast and in Canada, is present also in the Douglas-fir and true fir forests of the northern Rocky Mountains and the Pacific Northwest. Outbreaks of this insect, besides resulting in destruction of extensive stands of Douglas-fir in the Rocky Mountain region, have left many trees in a weakened condition that renders them susceptible to bark-beetle attack. Many other defoliators, by partially reducing the leaf surface of trees, adversely affect their growth; and in most cases the forester has little opportunity to prevent this damage.

Another indirect result of bark-beetle and defoliator damage is increase in forest-fire hazard. The old snags of insect-killed trees scattered throughout mature forests, averaging on some ponderosa pine areas as many as 10 per acre, stand for many years and greatly increase the cost, difficulty, and danger in fire control. The felling of snags is now required in many sales of national-forest timber, and many private operators have adopted this precautionary measure. The cost of controlling forest fires that have spread from burning snags within fire lines would alone justify large expenditures for insect control.

After the defoliation of large forest areas, the debris beneath

the stripped trees dries out quickly and becomes highly inflammable. A flash of lightning, or a carelessly handled match or cigarette sets off the mass, causing a widespread conflagration almost impossible to control. Heavy defoliations in Douglas-fir and hemlock stands and epidemics of the mountain pine beetle in lodgepole pine have put the forest in such a condition that, more often than not, forest fires have followed. The increased fire hazard is an added reason why forest-insect outbreaks should be controlled wherever possible.

RELATION OF INSECTS TO FOREST MANAGEMENT

Under virgin-forest conditions no checks were placed on the activities of destructive agents other than those imposed by Nature herself. Fires, as well as insects and disease outbreaks, developed, spread destruction, and ran their course. The whole process was very wasteful but seldom resulted in the permanent destruction of the forests over any large areas. Natural checks were imposed and the processes of regeneration were brought into play.

With the development of the country and a corresponding increase in values came the necessity for better protection and management. The first step in stopping Nature's wasteful processes was the control of forest fires. Later, with more intensive forest management and the development of control methods, attention was turned to the prevention of losses from forest insects and disease. As forest values increase, more and more attention will be given to preventing or controlling forest-insect damage, and a greater refinement in methods will become economically justifiable.

In a managed forest the first objective of forest-insect control is to so regulate conditions as to maintain a natural balance between the insect population that is destructive and the beneficial predacious forms, as well as between the insects and their food supply, to prevent the development of destructive insect outbreaks. This objective will be attained more fully in the future through silvicultural practices applied to growing stands whereby unfavorable conditions for the development of insects are maintained and a greater resistance of the stand to insect attacks is developed. This may involve such measures as prompt disposal of slash and correction of other insect-breeding conditions, the regulation of stand density and composition, the regulation of environmental factors through drainage or other methods, and the selection of insect-resistant varieties and species of trees.

When preventive methods fail to avert insect outbreaks, direct control measures must be considered. The total elimination of a forest insect is impractical, but fortunately this need not be attempted. Instead, the objective of direct control is the restoration of the natural balance in which the destructive insects are not greatly out of proportion to their natural enemies. In such proportions the destructive species are relatively harmless, and the damage they do is insignificant.

In view of present forest values it is hardly practical to attempt

to control all insect outbreaks. Much of the insect damage to forest trees of low value will have to be allowed to run its course, for if a policy of combating all threatening insect outbreaks were adopted the cost would be enormous and in many cases would exceed the damage probable if Nature were allowed to control the epidemic in her own way. The older forests, as they stand today, are ripe and an easy prey to bark-beetle attack, and if we are not prepared to utilize such timber and are willing to wait for Nature to replace any losses by the slow process of growing a new crop of trees, no further consideration need be given to control. But where timber is in demand and satisfactory control measures are available, failure to take the necessary protective measures should be viewed in the same light as failure to control forest fires.

DETERMINING CAUSES OF FOREST-TREE DAMAGE

Before observed damage is charged to insects, other possible causes should be investigated. Often several agents, such as fire, insects, fungi, and physiological injuries, are so closely associated or interrelated that it is difficult to determine the primary cause of the damage.

Injury by fire is usually easy to identify. Destruction of the ground cover, scorching of the bark, and reddening of the needles constitute ample evidence of fire damage. Usually bark beetles, either primary or secondary species, attack fire-weakened trees and complete their destruction. In some areas fire scars serve as important entrance points for fungi. Witches' brooms and damage by mistletoe are frequently conspicuous in either killing small trees or so distorting them that they can never grow into timber trees. Injuries by fungi, bacteria, and higher parasitic plants are not so easily determined by the layman, and can rarely be identified without the assistance of a trained forest pathologist. The diseases, decay, and wood rots caused by these various organisms are not discussed in this publication.

Mechanical and physiological injuries are frequently the primary cause of sickliness, weakness, or death of forest trees. The insects that invade the wood after such injuries have occurred are usually only secondary enemies, and cannot be charged with primary responsibility.

In some years a combination of weather conditions causes what is known as winter injury, red belt, or parch blight; that is, all trees of certain species on exposed hillsides within definite altitudinal limits turn a bright wine-red color. The injury is thought to be due to excessive transpiration during warm periods in winter when the ground, roots, and tree trunks are frozen and water cannot rise to supply the deficiency in the leaves. Twigs are sometimes killed, but the trees usually recover unless subsequently attacked by bark beetles or fungi.

Sometimes the tender bark on the south and southwest sides of trees and on the tops of branches is killed by the sun's heat. This is referred to as "bark scorch," or "sun scald." The bark breaks

away from the wood and sloughs off. Such damage often occurs when dense stands are opened up by cutting or where young trees are grown in exposed plantations.

Excessive quantities of dust in the air, as along dirt roads, causes a clogging of the stomata, or breathing pores, of leaves and results in partial suffocation of trees. In the Western States such injury is frequently followed by an attack of scale insects, which add to the injury and sometimes kill many young trees.

Trees are sometimes injured by smelter smoke and chemicals or oils deposited on the ground. This injury leads to attack by many species of insects. Flooding of trees usually kills them.

Trees may suffer mechanical injury from logging operations, lightning, road building, packing of soil or exposure of roots (as in camp grounds), or from the work of animals such as bears, beavers, and porcupines, and from sap-sucking birds. Such injury usually has little effect on a forest as a whole, and trees show remarkable power of recovery from limited mechanical injury, if it is not followed by the entry of insects or fungi.

Usually insect damage is readily apparent from the very start, but it is well to make certain whether other conditions are partly responsible before taking steps to control the insect pests. If they are not the primary cause, little benefit can be expected from the effort to control them.

A forest officer should become familiar with the appearance and characteristics of those insects capable of killing or injuring trees and destroying wood products on the area under his care. The insects he really needs to know are comparatively few, but ability to recognize the injurious forms comes only after considerable study, not only of the insect stages but also of their typical work, whether it be markings on the bark and wood, tunneling of needles, or deforming of terminals. In the following discussions special emphasis is placed on the habits and typical work of the most injurious forms; for it is through these that the forester first becomes acquainted with the destructive species, and only after considerable experience does he learn to recognize insect adults and larvae dissociated from their work and from typical host trees.

Adult insects can be distinguished from other small invertebrate animals by the fact that they have jointed bodies of three parts (head, thorax, and abdomen), breathe through tracheae, and have one pair of antennae and three pairs of legs.

The larva is the form most frequently encountered by the forester; but unfortunately it is difficult to distinguish insects in this form by any simple characters. Usually it is sufficient for the forester to be able to recognize the larvae as belonging to a certain group. The forester easily acquires the ability to recognize some of the more common forms through becoming familiar with their work.

The insects most important to forestry are included in seven main groups, or orders, under the large class Hexapoda, or Insecta (*47*).[1] These common groups (fig. 4) include the beetles (Coleoptera (*99*)), butterflies and moths (Lepidoptera), wasps (Hymenoptera), flies (Diptera), scales and aphids (Homoptera), bugs

[1] Italic numbers in parentheses refer to Literature Cited. p. 246.

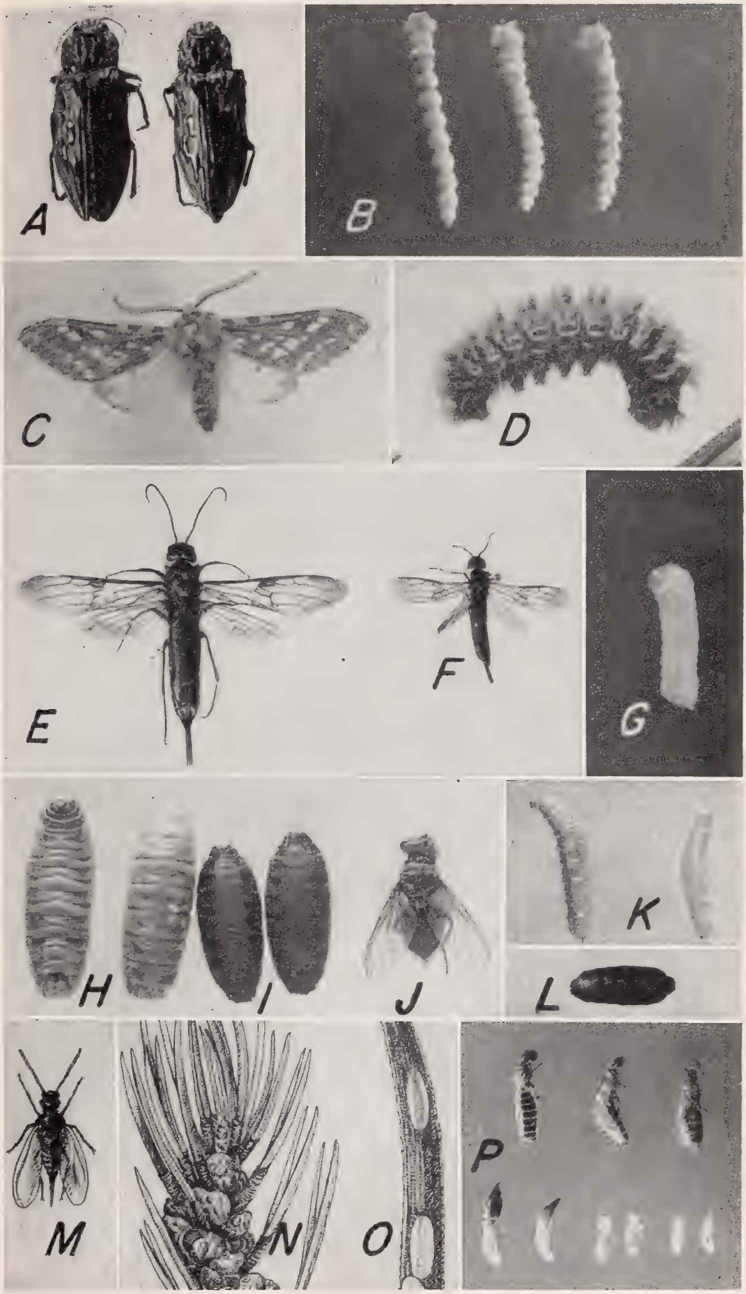

FIGURE 4.—Examples of insects in orders to which most forest insects belong. Beetles (Coleoptera): *A*, Adults; *B*, larvae. Moths (Lepidoptera): *C*, Adult; *D*, caterpillar. Wasps (Hymenoptera): *E*, Adult female; *F*, adult male; *G*, grub. Flies (Diptera): *H* and *K*, Maggots; *I* and *L*, puparia; *J*, adult. × 2. Scale insects (Homoptera): *M*, Adult male; *N* and *O*, scales on pine needles, greatly enlarged. (Drawings by Edmonston.) *P*, Termites (Isoptera). Natural size except where otherwise indicated.

(Hemiptera), and termites (Isoptera). There are a number of other orders of insects, but these are less frequently encountered. Some small animals closely related to insects, and frequently confused with them, are of importance in forestry. The mites, belonging to the class Arachnida, are sometimes injurious to trees. The spiders, belonging to the same class, are predaceous and usually beneficial. The millipedes and centipedes, belonging to the classes Chilopoda and Diplopoda, are occasionally of importance in the forest.

Most insects pass through either three or four stages of development. The beetles, wasps, flies, butterflies, and moths pass through four such stages, and so are said to undergo complete metamorphosis. The adult female lays eggs, from which the second stage, the larvae, develop. The larvae usually are soft bodied and wormlike. The larvae of beetles are called grubs; those of moths and butterflies are called caterpillars; those of flies with two clear wings are called maggots; and those of wasplike flies with four clear wings are called grubs, slugs, or false caterpillars. The larvae feed and grow, the final size which they attain being influenced to some extent by the abundance of food and moisture. As they increase in size they molt or shed their skins several times. The larvae transform to the pupal or resting stage, and the pupae in turn change to the fourth stage, the adult insects. Growth takes place only in the larval stage. Although some adult insects do some feeding, none of them increase in size. Their chief function in life is to mate and produce eggs, and thus initiate another life cycle.

Scale insects, aphids, bugs, and termites undergo what is called an incomplete metamorphosis; that is, they have only three forms—the egg, the nymph, and the adult. Growth takes place during the nymphal stage, in which the insect has very much the form and appearance of the adult, but lacks fully developed wings.

Certain insects, such as the termites, aphids, and ants, have several specialized adult forms. Thus, in addition to the usual stages, there may be workers, soldiers, and secondary sexual forms. Certain scale insects and aphids give birth to living young without producing eggs. Others are able to reproduce by means of eggs laid by virgin females, which develop without being fertilized. In some cases, as among the gall midges, larvae are able to give birth to similar larvae without passing through other stages. These are all exceptions to the general rule.

Insect damage to trees may be caused in any one of several ways. Adults of some species cause injuries by feeding on the leaves, twigs, or tender cambium, or by slitting bark or leaves in order to deposit eggs. Adult bark beetles do considerable damage in constructing egg tunnels under the bark. Most commonly, however, the damage is done by the larvae or nymphs in their feeding on various parts of the tree. No damage is ever done by the insects while in the egg or pupal stages.

The principal methods of feeding by which insects injure trees are chewing, sucking, and gall forming. The great majority of forest insects belong to the chewing group, and in the larval or the adult stage, or both, these chew and ingest plant material. This

group includes the leaf eaters, the cambium miners, and the wood borers. Aphids, scale insects, and bugs suck plant juices by means of slender mouth parts, which they insert into the tender portions of the tree. A group of specialized insects irritate portions of the tree and thus cause it to form a swelling or gall, which encloses them. The method of feeding has an important bearing on the methods of control.

The important forest insects might be classified, for the purpose of discussion, according to their natural relationships (*45*), according to the species of trees attacked, according to the parts of the tree affected, or according to the stage of the life of a forest tree upon which they inflict their greatest injury. For the purposes of this publication, it seemed that the last-mentioned classification would be most helpful to the forest field man. In this publication, therefore, the western forest trees will be followed through their life cycle, from seed to final finished product, and at each step the insects of greatest importance in injuring them will be discussed.

INSECTS AFFECTING SEED PRODUCTION

The natural reproduction of forests, the artificial reforestation of denuded areas, and the future supply of timber depend to a considerable extent on the production of a prolific supply of sound, uninjured seed. In most instances insect damage to tree seeds is not severe enough to be of great importance; in some seasons, however, insects destroy practically all the seed of certain tree species in certain localities.

Destruction of seeds may be caused by insects that attack the buds, flowers, or immature cones, as well as by those that attack the seeds themselves. Damage at these early stages causes wilting, blighting, or premature dropping of the parts affected. The fruit or cones developing after insect attack may be deformed or "wormy," riddled by the borings of various grubs, caterpillars, or maggots. In many cases the cones show no damage, but the seeds are infested with the small white larvae of seed chalcids. Even the old, hard, dry cones of certain pines are often mined by wood borers. The insects that affect seed production in these various ways belong to a number of different orders and families, of which some work only on cones or seeds, whereas others work also in the bark or cambium of succulent growing shoots, stems, and twigs, or even in dry wood.

Knowledge of the presence of seed-infesting insects will often prevent the disappointment and loss attendant on the collecting, handling, and sowing of insect-damaged seeds (*115*).

Key to Diagnosis of Insect Injury to Cones and Seeds

A. Insects boring through fresh green cones and coniferous seeds.
   1. Cones wither and die before they are half grown.
      a. Interior of pine cones mined by small, dark-brown beetles and small, white, curled larvae. . Cone beetles (p. 18)
      b. Fir, spruce, and other cones deformed and showing exudation of pitch or webbed borings; interior mined by active caterpillars . . . . Cone moths (p. 19)

Key to Diagnosis of Insect Injury to Cones and Seeds (Cont.)

2. Cones reach full growth but are riddled with insect borings.
   a. Borings made by active caterpillars which leave pitchy masses of boring and excrement within the cone and similar exudations at the point of entrance, or larval mines in axis and mature seeds, without resinous exudations.................... Cone moths (p. 19)
      (1) Large reddish-green caterpillars throwing out webbed frass, with little or no pitch exuding; pine, fir, and spruce cones *Dioryctria* spp. (p. 20, 22)
      (2) Similar caterpillars in cypress and Sitka spruce cones .... *Heinrichia* spp. (p. 23)
      (3) Similar work but caterpillars of "measuring worm" type .... *Eupithecia* spp. (p. 22)
      (4) Large white caterpillars, causing considerable pitch flow and resinous masses in fir cones *Barbara* spp. (p. 21)
      (5) Small pink or gray-white caterpillars with black heads boring within silken-lined tunnels mostly through axis of cones and into the seeds .... *Laspeyresia* spp. (p. 20, 22)
      (6) Small white or pink caterpillars boring through pine cone scales.... *Eucosma* spp. (p. 20)
   b. Chewing by slugs on fresh cones of incense cedar Incense cedar sawfly (p. 23)
   c. Soft fir cones riddled by small, white, slim, maggots which leave fine excrement in tunnels, but free from masses of pitch.................... Cone maggots (p. 23)

B. Old, persistent, hard, dry pine cones mined by slender, white, roundheaded or flatheaded larvae................ Cone borers (p. 23)

C. Insects attacking coniferous seeds only.
   1. Seeds show no external injury, but contain small, white, curled, legless grubs in interior cavity..... Seed chalcids (p. 24)
   2. Seeds swollen and galled, containing small, pink maggots Seed midges (p. 23)

D. Injuries to nuts or seeds of broad-leaved trees.
   1. Seeds, nuts, or acorns showing no external injury but mined by small, white, curled, legless grubs.
      a. In oak acorns and hazel nuts........ Acorn weevils (p. 26)
      b. In ash seeds .... Ash-seed weevil (p. 26)
      c. In mesquite, acacia, horsebean, catclaw, palo-verde, and locust .... Bean weevils (p. 27)
   2. Interior of seeds or acorns mined by active caterpillars which discharge webbed frass through exit hole.
      a. In oak acorns and hazel nuts......... Filbertworm (p. 26)
      b. In maple .... Maple seed caterpillar (p. 26)

CONE BEETLES

Pine cones that dry and wither before they are half grown, and either drop to the ground or are retained as blighted immature specimens, usually have been killed by the cone beetles (*Conophthorus* spp.) (*116*).

The adults are small, dark, shining cylindrical beetles, from $1/16$ to $5/32$ inch in length. They bore into the base or supporting stem of the immature pine cones in the spring soon after the beginning of the second year's growth. A small tunnel is projected through the axis of the cone, and in this the female beetle deposits her eggs. From these hatch small, white, curled, legless grubs, which feed on the scales, seeds, and tissues of the withering cone. Development to the adult stage is completed during the summer within

the dead cone, where the beetles usually remain over the winter. The damage to the cone crops of ponderosa, western white, and sugar pines is often very severe. In some years from 25 to 75 percent of the sugar pine cones have been killed over large areas. In other pines the damage is less conspicuous. Spraying cone-bearing trees with DDT early in the spring to prevent attack might prove effective.

A number of species found in western pines have been described by Hopkins—and named for their principal host trees. The following list gives the species of *Conophthorus* that may be found in western forests:

Species of *Conophthorus*	*Hosts and distribution*
apachecae Hopk.	Apache pine. Arizona.
contortae Hopk.	Shore pine. Oregon coast.
edulis Hopk.	Pinyon pine. Colorado, Arizona, and New Mexico.
flexilis Hopk.	Limber pine. Colorado and Montana.
lambertianae Hopk. (*fig. 5*)	Sugar pine and western white pine. Oregon and California.
monophyllae Hopk.	Singleleaf pine. Southern California.
monticolae Hopk.	Western white pine. Idaho, Washington, and Canada.
ponderosae Hopk.	Ponderosa pine and Jeffrey pine. Pacific Coast States.
radiatae Hopk.	Monterey pine. California.
scopulorum Hopk.	Ponderosa pine. Rocky Mountain region.

FIGURE 5.—The sugar pine cone beetle (*Conophthorus lambertianae*): *A*, Adults, slightly enlarged; *B*, pitch tubes on stems of blighted sugar pine cones, indicating cone beetle attack.

CONE MOTHS

The caterpillars of certain species of moths feed on the bracts, scales, and seeds of tender growing cones. Such feeding dwarfs or deforms the cones and sometimes causes their death, but more frequently destroys a large percentage of the seeds without killing the cones. The work of certain species is characterized by larval tunnels within the cones and an opening at the surface through which resin mixed with larval castings exudes. Other caterpillars attack the cones and mine through the axis and into the seeds without causing resinous masses or deformity of the cones.

The adults are mostly small inconspicuous moths, which are seldom noticed. They usually fly early in the spring and deposit their eggs on the scales of young cones. The eggs hatch in a few days, and the young larvae bore into the cones, where they feed until fall. When the caterpillars reach full growth they form silken cocoons on the surface of the cones, among the cone scales, or in the pith, in which they overwinter. Most moths have one generation annually, and the adults emerge the following spring, but a few may be retarded in their emergence and appear the second or third season. Thus in the event that one or two cone crops fail, the species is still able to survive.

Control of cone moths has never been attempted but might be possible through aerial application of DDT before egg laying begins.

PINE CONE MOTHS

Pine cones are attacked early in the spring of their second year of growth by caterpillars of cone moths. The species most commonly involved in this type of injury is the pine cone moth *Laspeyresia piperana* (Kearf.). The dirty-white caterpillars are about ½ inch long when full grown. They burrow through the central axis of the cones and enter the seeds through the point of attachment. They are especially destructive to the seeds of ponderosa pine (fig. 6) and Jeffrey pine in California, Oregon, Washington, Idaho, and Montana. Pupation takes place in the pith. The moths are small, ½ inch long, and range in color from gray to black.

Other cone moths that attack pine cones bore tunnels through scales and seeds. The seeds and a large portion of the interior of the cone are destroyed. Sometimes the attack distorts and deforms the cone or kills it before it reaches maturity. Most of the species of this group also feed on the succulent new growth of pines. Their work is characterized by a resinous exudation of pitch and larval castings mixed with webbing. The following species belong in this group:

Species	*Hosts and distribution*
Dioryctria abietella (D. & S.)	Pines, Douglas-fir, balsam fir, and spruce. California, Oregon, Washington, Arizona, Colorado, and Wyoming.
albovittella (Hulst)	Singleleaf pine. Nevada.
xanthoenobares Dyar	Ponderosa pine, knobcone pine, and other pines. California, Oregon, Colorado, and Montana.
Eucosma bobana Kearf.	Ponderosa pine, Jeffrey pine, and knobcone pine. California, Oregon, and Montana.
rescissoriana Hein.	Lodgepole pine. Oregon.

FIR CONE MOTHS

Cones of white, red, and other true firs, and of Douglas-fir, are most seriously injured by the attack of small moths of the genus *Barbara*. The yellowish-white caterpillars mine through

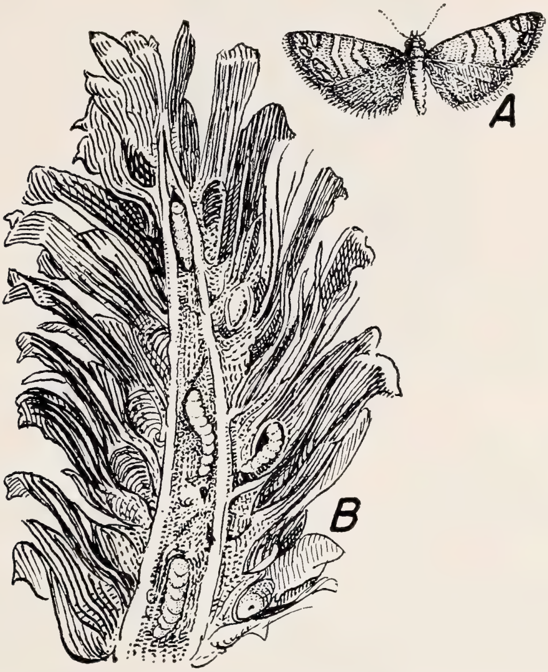

FIGURE 6.—A pine cone moth *Laspeyresia piperana*: *A*, Adult, × 2; *B*, caterpillars feeding through ponderosa pine cone; pupa in pith. (Drawing by Edmonston.)

scales and seeds, making a tortuous resinous tunnel and an opening at the surface through which resin and larval castings exude. The pupae overwinter near the axis of the cone in a papery, resin-coated cocoon among the resin-matted scales. The adults, which are gray moths about ½ inch long and with speckled forewings, emerge the following spring and lay their eggs on the young tender budding cones. The several species and varieties listed below cause this type of damage:

Species of *Barbara*	*Hosts and distribution*
colfaxiana Kearf.	Douglas-fir. California, Oregon, Washington, and British Columbia.
colfaxiana var. *taxifoliella* Busck	Douglas-fir. Idaho and Montana.
colfaxiana var. *coloradensis* Hein.	Douglas-fir and white fir. Colorado.
colfaxiana var. *siskiyouana* Kearf.	White fir and red fir. California and Oregon.
ulteriorana Hein.	Douglas-fir. Oregon.

Similar damage to fir cones is frequently caused by the caterpillars of a cone pyralid and a fir cone geometrid.

FIGURE 7.—The pyralid *Dioryctria abietella,* slightly enlarged, and typical damage to Douglas-fir cones. (Drawings by Edmonston.)

The cone pyralid *Dioryctria abietella* (D. & S.) (fig. 7) in the full-grown larval stage is a large, active, irridescent, greenish-red caterpillar ¾ inch long, which bores through scales and seeds of Douglas-fir, true fir, pine, and spruce cones, leaving a round clean-cut hole. In contrast to the work of *Barbara,* its webbed castings on the surface of an infested cone are free from pitch. The adults are gray moths mottled with black and having a wing expanse of about 1 inch.

The fir cone geometrid *Eupithecia togata spermaphaga* (Dyar) in the adult stage is a gray moth with black and red-brown markings and a wing expanse of about 1 inch. The caterpillars are of the measuring-worm type. They bore through seeds and cone scales of Douglas-fir, the true firs, mountain hemlock, and probably other conifers.

OTHER CONE MOTHS

Another group of small moths, belonging to the genus *Laspeyresia,* are destructive to fir, spruce, and other cones. The pink or white larvae are less than ½ inch long when full grown, and have a few bristles. The moths are small and dull-colored. The small, pink larvae of *L. bracteatana* (Fern.) bore into the seeds of white, red, and other firs in Oregon, California, and Colorado. *L. youngana* (Kearf.) has white larvae with black heads. These larvae work mostly in the axis of Engelmann, blue, and Sitka spruce cones in Colorado, Montana, and Oregon. The small grayish-white

larvae of *L. cupressana* (Kearf.) bore in the green-cone clusters of Monterey and other cypress in California. (See p. 53.)

The large greenish-red, purplish to reddish-brown larvae of *Heinrichia macrocarpana* (Wlsm.) bore through the cones of Monterey cypress and also feed on the cambium of twigs. *H. fuscodorsana* (Kearf.) does similar work in Sitka spruce cones.

Cones of incense cedar in Oregon are sometimes injured by the slugs of a sawfly *Augomonoctenus libocedri* Rohw., which does work similar to that of cone-feeding caterpillars. The adults are ¼ to ⅜ inch long, shining blue-black, with the first five segments of the abdomen brick red.

CONE MAGGOTS

The insects encountered in seed collecting probably more often than any other group are small, white or pink, legless maggots, which emerge in vast numbers from cones spread out to dry. These are the larvae of tiny gnats, midges, or flies. A few cause considerable injury to cones and seeds, whereas others do no appreciable damage.

Cone and seed midges (Itonididae) are found in cones as small pink maggots, the larvae of small gall gnats or midges. The adults are small and very similar in appearance to mosquitoes. They lay their eggs on the young, green cones, and the maggots work within and cause little masses of resin to form among the cone scales or cause hard resinous galls to form on the scales or in the seeds. The damage from these insects is usually insignificant. Of the many western species, only one, *Janetiella siskiyou* Felt, from the seeds of Port Orford cedar, has been named.

The white fir cone maggot (*Lonchaea viridana* Meig.) is the common white maggot found so abundantly in white fir and other true fir cones (fig. 8). These maggots mine through scales and seeds, often causing great damage. The larvae leave the cones as soon as they fall and form small puparia in the ground. Here they overwinter, and in the spring some of them emerge as small, black, shining flies. Most of the brood go through a 2-year life cycle, emerging the second spring after beginning pupation.

CONE BORERS

The hard, dry cones of certain pines are frequently attacked by the larvae of flatheaded and roundheaded borers, which riddle the interior and destroy the seeds.

The roundheaded cone borer (*Paratimia conicola* Fisher) bores tunnels through the hard pitch and scales of knobcone pine cones. It works also in the dry limbs of this pine and has been recorded from the cones of shore pine in California. The adults are rusty reddish-brown, and are ½ inch long.

The flatheaded cone borer (*Chrysophana placida conicola* Van D.) has been found boring through the hard, dry cones of knobcone, Coulter, and ponderosa pines. The species *C. placida* Lec. bores in the dead limbs, branches, trunks, and stumps of practic-

ally all western pines and firs. The adult is a small green or greenish-red beetle, about ½ inch long. **The roundheaded borer** (*Phymatodes nitidus* Lec.) is frequently found in redwood cones.

FIGURE 8.—White fir cone maggots (*Lonchaea viridana*), commonly destructive to seeds of white fir. × 2.

SEED CHALCIDS

Seeds of many conifers are attacked by small wasps of the genus *Megastigmus* (*123*), which drill through the young green cones with their long ovipositors and lay their eggs within the immature seeds (*117*) (fig. 9). The small, white, legless larvae feed on and destroy the tissue within the seeds. The normal outer shell is formed later and the surface shows no evidence that the seed is infested. The feeding habits of these insects are similar to those of the gall makers. In the following spring the larvae reach maturity and adults emerge as small yellow or nearly black wasps. Each adult leaves a smooth round emergence hole in the seed coat. Some hold over and emerge the second or even the third year. The damage by these seed-infesting insects is an important factor in seed collecting, and often a high percentage of cleaned commercial seed will be found to have been ruined by these insects.

There appears to be no practical means of preventing damage by seed chalcids. If seeds are to be shipped to other countries, it may be desirable to fumigate them before shipment. Any of the common grain fumigants may be used. These fumigants will not injure germination, provided the moisture content of the seed is not over 12 percent and exposures are limited to 24 hours. Recommended dosages per 1,000 bushels of seed are 15 pounds of cal-

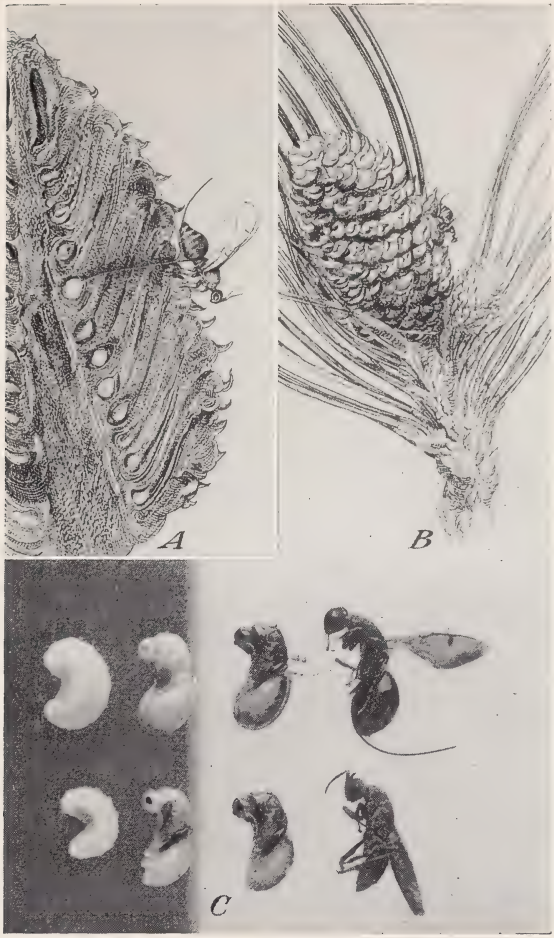

FIGURE 9.—Ponderosa pine seed chalcid *Megastigmus albifrons*: *A* and *B*, Adults laying eggs through small green cones into seeds (drawings by Edmonston), enlarged; *C*, larvae, pupae, and adults, × 3; females above, males below.

cium cyanide, or 3 gallons of carbon disulfide, or 6 gallons of a 3-to-1 mixture of ethylene dichloride and carbon tetrachloride. Methyl bromide also has been successfully used as a fumigant. Recommended dosages per 1,000 cubic feet are 2.5 pounds for 16-hour exposure or more, at temperatures of 60°–75° F.; 4 pounds for 4 hours at 50°–70° or for 2 hours at 70° or above. Insects in seed may also be destroyed by fumigation at 140° for 10 minutes without injuring germination unless the seed is of low vigor or its moisture content is high.

The different species of the genus *Megastigmus* and the hosts from the seeds of which they have been reared are as follows:

Species of *Megastigmus*	*Hosts and distribution*
albifrons Wlkr.	Ponderosa pine. Arizona, California.
lasiocarpae Crosby	Alpine fir, Pacific silver fir. Colorado, Washington.
milleri Milliron	Grand fir, Shasta red fir. California, Canada (British Columbia).
piceae Rohw.	Blue spruce, Engelmann spruce, Colorado. Sitka spruce, California, Oregon.
piceae var. *montana* Milliron.	Engelmann spruce. Montana.
pinus Parfitt	Pacific silver fir, grand fir, white fir, California red fir, Shasta red fir, Noble fir. California, Oregon, Washington, Nevada, Colorado, Idaho.
rafni Hoffmeyer	White fir, grand fir, California red fir, Shasta red fir. California, Colorado, Idaho, New Mexico, Oregon.
spermotrophus Wachtl	Douglas-fir. Western U. S. and Canada.
spermotrophus var. *nigrodorsatus* Milliron	Bigcone spruce. California.
tsugae Crosby	Mountain hemlock. Oregon and Washington.

OTHER TREE SEED INSECTS

Nuts and acorns of various western hardwoods are frequently infested by the curled white grubs of the nut and acorn weevils, belonging to the genus *Curculio*. The adults are medium-sized, yellow, brown, or nearly black weevils with robust bodies, long legs, and prominent, slender, curved or nearly straight beaks. The adults appear in the summer. With their beaks they gnaw holes in the shells of new acorns or nuts and in these they place their eggs. The larvae feed on the meat and destroy the seed. The winter is passed in the larval stage, either within the acorn or in the ground. Pupation occurs the next spring, and the adults emerge in the summer. Several species of *Curculio* are found in oak acorns in the Western States. The most common of which is **the filbert weevil** *Curculio uniformis* (Lec.), which is distributed through New Mexico, Arizona, Utah, California, Oregon, and Washington.

The filbertworm (*Melissopus latiferreanus* (Wlsm.)), a small white or pinkish caterpillar about ¾ inch long, may be found boring through oak acorns and galls, hazelnuts, filberts, chestnuts, chinquapin, Catalina cherry, and various other fruits and nuts throughout the United States. In the Pacific Northwest there is one, and a partial second, generation a year. The larvae hibernate in cocoons beneath or on the surface of the ground, or in the damaged host. Emergence of adults seems to be synchronized with the formation of nuts or acorns.

The maple seed caterpillar (*Proteoteras aesculana* Riley) works in the seeds of bigleaf maple, completely mining them out.

The ash seed weevil (*Thysanocnemis* sp.) is a small yellow weevil ⅛ inch long, which lays its eggs in a puncture on the young developing seeds of ash. The tiny larvae penetrate the seed without

leaving a visible sign, and the small, white, legless larvae develop within the seed coat, completely consuming the cotyledons. The full-grown larvae leave the seed late in the fall or winter to pupate in the ground, from which they emerge as adult weevils late in June and throughout July. Sometimes over 60 percent of the seed crop is thus destroyed. This weevil has been reared from Oregon ash in Oregon and Washington.

In the Southwest forest trees belonging to the family Leguminosae—such as cat's claw (*Acacia*), mesquite (*Prosopis*), horsebean (*Parkinsonia*), palo-verde (*Cercidium*), and locust (*Robinia*)—frequently have their seeds infested and destroyed by the small, white, curled, legless grubs of species of bean weevils of the genus *Bruchus*. The adults are small, stout, brown to black beetles about 1/8 inch long.

INSECTS INJURIOUS TO FOREST NURSERIES

A forest nurseryman must guard against insect enemies of young trees, as well as against damping-off, rodents, heat injury, and unfavorable soil conditions. Young seedlings in seed and transplant beds are frequently damaged by root-feeding insects, which are able to inflict more injury at this stage than later, after trees have become established and have developed larger root systems. The stems of young seedlings may be attacked above ground by cutworms, grasshoppers, leafhoppers, aphids, and various bark-chewing beetles; and the leaves may be fed upon by caterpillars, sawflies, and various scales, aphids, and bugs.

In western forest nurseries, white grubs, strawberry root weevils, seed-corn maggots, cutworms, symphylids, grasshoppers, and aphids are some of the pests that have been particularly troublesome. But in general these nurseries have been more fortunate than those in the East in escaping insect pests (*107*).

Although the control of insect pests in forest nurseries is sometimes a difficult matter, the nurseryman has measures at his disposal which would be impractical to use under forest conditions. Most root-feeding insects can be controlled by applying a soil fumigant, or by using poisoned baits, but much can be done to avoid injury through regulating cultural methods. Certain new soil fumigants, such as D-D (dichloropropane-dichloropropylene) and ethylene dibromide have largely taken the place of the older soil fumigants, such as carbon disulfide, chloropicrin, calcium cyanide, dichloroethyl ether, paradichlorobenzene, and naphthalene. Transplant beds that have become heavily infested should be plowed and allowed to remain fallow for at least a year. If they are cultivated often enough to prevent the growth of weeds, most of the insects will have been starved out in a year's time, and the beds can be used again for a short period without serious injury

to transplants. Leaf-feeding insects usually are easily controlled by the use of sprays.

Key to Diagnosis of Insect Injury to Forest Nursery Trees

A. Roots of seedlings completely bitten off or the bark badly chewed,[1] injured, or dying. Look for soil-inhabiting insects appearing as—
   1. Curled, white grubs, with three pairs of prominent legs and with brown heads[2] .... White grubs, p. 28
   2. Small, curled, white grubs with small, brown heads but without legs[2] .... Root weevils, p. 29
   3. Long, slender, hard-shelled, yellow or brown "worms" with feebly developed legs[2] .... Wireworms, p. 30
   4. Nearly hairless, soft, sluggish, dark-colored caterpillars working below surface of ground[2] .... Cutworms, p. 30
   5. Soft, white, slim, legless maggots burrowing within stem below ground .... Seed-corn maggot, p. 31
   6. Small, white, centipede-like animals found in moist soil Symphylids, p. 31

B. Stems of young seedlings bitten off, badly chewed, or injured.[3]
   1. Nearly hairless, sluggish caterpillars working at night Cutworms, p. 30
   2. Grasshoppers .... Grasshoppers, p. 74

C. Leaves of seedlings either chewed, skeletonized, mined, discolored, or attacked by leaf-sucking insects .... Defoliators, p. 75

[1] Damage meeting this description is done also by root-feeding mammals such as gophers, and squirrels.

[2] These characters are not specific and sometimes noninjurious larvae of similar appearance may be confused with these forms.

[3] Similar damage is often done by small animals, such as mice, squirrels, and porcupines.

WHITE GRUBS

White grubs (*41, 85, 105*) (fig. 10), the larvae of June beetles (*Phyllophaga* spp., *Polyphylla* spp., and other related genera), may be encountered in forest nurseries, particularly where the land has previously been covered with weeds and grass. The white grubs feed on the roots of a great variety of plants and the adult beetles are voracious feeders on the leaves. A large number of species are widely distributed throughout the United States.

The large, shining, brown June bugs usually lay their eggs in the spring of the year in grassy places or where the ground vegetation is heavy. The grubs hatch 3 or 4 weeks later. In the North, where the life cycle usually requires 3 years, the small white grubs feed during the first summer on organic material and on small rootlets near the surface of the soil. As cold weather approaches they burrow more deeply into the soil and hibernate. The second season the grubs are larger and do their greatest damage to the roots of seedlings and small trees. They again hibernate deeply in the soil over the second winter, and again feed near the surface the following spring. The full-grown grubs are white, thick-bodied, with dark-brown heads and three pairs of well-developed legs. They always lie in a tightly curled position and are familiar objects to everyone who has dug for fish bait. Usually in midsummer of the third season they reach full growth, and then transform

to pupae and new adults within a cell in the ground, where they remain over winter, and emerge the following spring as full-grown beetles.

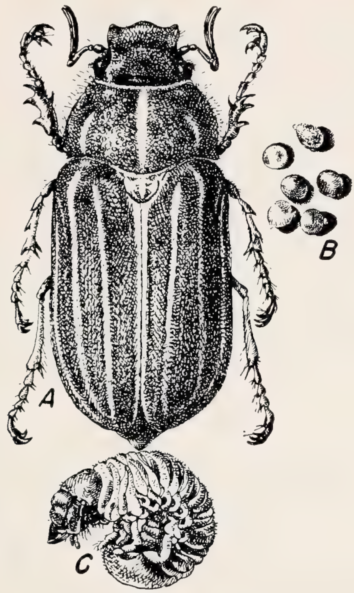

FIGURE 10.—*Polyphylla crinita* Lec.: Adult beetle, eggs, and larva or white grub. All × 2. (Drawings by Edmonston.)

White grub damage can be largely prevented by cultural operations. New ground that is to be used for transplant beds should be cultivated 2 or 3 years before planting, to allow for the emergence of beetles already in the ground and to avoid new egg laying. If the ground is thoroughly worked over with a rotary tiller about the end of June and again about 3 weeks later, a high percentage of white grubs will be killed and damage will be comparatively light. Damage from white grubs in western forest nurseries has not required any further control action than these preventive cultural practices.

ROOT WEEVILS

In forest nurseries of the Pacific Northwest, and elsewhere (*106*), the strawberry root weevil is one of the most serious insect pests. Three species of *Brachyrhinus,* of which the most common is **the strawberry root weevil** (*B. ovatus* (L.)), have been known to damage roots of coniferous seedlings (*57*). The adults are small, brown, hard-shelled, wingless beetles about ¼ inch long, with head extended into a snout. When the adult weevils emerge early in the summer, they migrate on foot, crawling everywhere, in search of suitable places for egg laying. Eggs are laid on the ground around the crown of plants, and the small, white, curled grubs develop in the soil, where they feed on the roots of various

plants. The larvae hibernate at depths of 6 to 14 inches below the surface of the ground. In the spring the larvae resume feeding and do their greatest injury to roots as they work upward. The full-grown larvae pupate in the soil and emerge as new adults late in the spring and summer, mostly during June and July.

Seedbeds can be protected from infestation by encircling them during the migration and egg-laying period with barriers, such as boards or metal strips placed on edge in the ground and painted with sticky substances such as coal tar or tree-banding material, or by spraying with DDT to kill the migrating adults. Poison baits, containing 5 pounds of powdered calcium arsenate or sodium fluosilicate and 95 pounds of ground dried-apple waste, applied at the rate of 50 to 70 pounds per acre, have proved effective in large fields.

Infestations may be prevented through clean cultivation and rotation of seed and transplant beds, allowing infested plots to remain fallow and be cleanly cultivated in alternate years.

WIREWORMS

Under certain conditions wireworms (Elateridae) (*83*) may prove to be troublesome nursery pests. They are most frequently found in heavy, moist soil, where they feed on undecayed plant material and small roots. These long, slim, cylindrical, hard-shelled "worms" with feebly developed legs are the larvae of click beetles, which can be easily recognized by their ability to flip into the air for several inches when turned on their backs.

The new soil fumigants D–D and ethylene dibromide have proved effective in wireworm control. D–D is applied at the rate of 400 pounds (40 gallons) per acre at a depth of 6 to 8 inches, and ethylene dibromide at 10 percent by volume (or 20 percent by weight) strength dissolved in a naphtha 200-base thinner at the rate of 20 gallons per acre. These soil fumigants are applied at least 15 days before planting, when the soil is not too wet or too dry and the temperature at the 8-inch depth is not below 50° F.

CUTWORMS

From time to time cutworms make their appearance in forest nurseries and do considerable damage to the young trees by feeding on the roots or clipping off seedlings at the ground line.

The adults of cutworms are the dull-colored, yellow, tan or brown moths that collect around lights at night and are commonly referred to as "millers." They fly at night, usually early in the spring, and lay their eggs on the ground where there is ample vegetation for larval food. The larvae, or cutworms, work underground, feeding on the roots of various plants, or during the night they often feed above-ground on the foliage or clip off the stems at the ground line. They are dull-colored, with few or no hairs on the body, and some have a greasy, slimy appearance in keeping with their ground habitat. They reach full growth late in the summer or in the fall and overwinter in the soil as full-grown larvae

or as pupae in earthen cells. Emergence takes place the following spring. Some species may have several broods a year.

Clean culture in the nursery to avoid the establishment of weeds or ground cover that would be suitable for egg laying, and cultivation in the fall and winter to destroy the hibernating larvae, will do much to prevent cutworm damage. Where such methods fail, commercially prepared poison baits scattered over the beds just before dusk are effective, or the beds may be dusted with cryolite or DDT.

MAGGOTS

The seed-corn maggot (*Hylemya cilicrura* (Rond.)) is a common pest of various farm crops, but is comparatively rare in forest nurseries. It has been reported from forest nurseries in the East, but in the West has been found only in one nursery at Nisqually, Wash., where 40 to 50 percent of Douglas-fir seedlings were lost in 1944 because of its injury. Spruce seedlings were also attacked.

The seed-corn maggot passes the winter in the prepupal or pupal stage within a brown puparium, about the size of a grain of wheat, at a depth of 6 to 7 inches in the soil. In April the ash-gray flies, about $3/16$ inch long, with the two wings folded back so the outer edges are nearly parallel, emerge and lay their eggs in the soil just as the ground begins to crack above the germinating seed. The soft-bodied, yellowish-white, legless maggots burrow through and beneath the thin bark of the stem and feed up to a short distance above the ground and down into the roots. The maggots are approximately $1/4$ inch long when full grown. Maximum damage is done early in the spring on cold, wet sites where the soil has an abundance of organic matter. Adults emerge late in July or early in August. There are two generations a year.

The following methods of control have been proposed:

(1) Delaying planting to avoid the cold, wet period most favorable for egg laying.

(2) Applying a DDT spray (2 pounds of 50-percent wettable powder to 100 gallons of water) at the rate of $2\frac{1}{2}$ gallons per 1,000 square feet of seed bed, just as the ground begins to crack above the germinating seed, to prevent egg laying.

(3) Applying an inorganic fertilizer in the fall prior to planting or after the seedlings are $1\frac{1}{2}$ to 2 inches above ground.

(4) Fumigating the soil before planting with carbon bisulfide (1 quart of 50-percent miscible to 50 gallons of water) at the rate of 1 pint per square foot, or with D-D mixture or ethylene dibromide at the rates given for control of wireworms (p. 30).

SYMPHYLIDS

Symphylids, or garden centipedes, are slender, white, active creatures about $1/4$ inch long. They thrive in damp soil with abun-

dant humus and feed on the roots of various plants. They are most injurious early in the spring. At the State nursery at Corvallis, Oreg., hardwood seedlings have been damaged, but conifers are not seriously affected (*124*). Soil fumigation with D–D mixture or with ethylene dibromide before planting has proved effective under experimental conditions.

APHIDS

Aphids (see p. 56) are often found in clusters on the tender, growing tips of nursery stock. Usually they are not abundant enough to cause appreciable injury, but, if they are, they can be easily controlled with a miscible oil or nicotine sulfate spray.

INSECTS INJURIOUS TO YOUNG TREES

(SEEDLINGS, SAPLINGS, AND POLES)

Trees in plantations and forests are subject to attack by a great many insect pests while they are growing from seedlings to maturity. At first they may be attacked by root-feeding insects. Later another group of insects feed on the rapidly growing terminal shoots, laterals, tips, or buds. This type of damage seldom kills the young trees, but it often seriously deforms or stunts them. As buds and terminals are killed, the tree throws out new buds and shoots, which results in much branching. The tree becomes bushy, with the main trunk crooked and gnarled, and is often permanently ruined for commercial use. At this stage of the tree's life, leaf-eating and bark-feeding insects also begin to be important.

The control of insects affecting young trees rarely calls for direct control measures. A certain amount of insect damage is normal in natural forests and is only a part of the natural thinning process. When an epidemic develops as the result of some disturbance of the natural balance, as through the creation of an abundance of slash, windfall, or fire-injured trees, some direct control action may be necessary to protect the younger trees. Usually the indicated remedy is avoidance of the conditions that induce epidemics or the prompt disposal of breeding material. In plantations, or on trees of special value, some attention to insects may be justified.

Key to Diagnosis of Insect Injury to Young Trees

A. Entire tree, or large part, sickly, dying, or dead; foliage fading, turning yellow or red.
   1. Tunnels or borings found under the bark of the main trunk or larger branches............Cambium feeders, p. 126
   2. Foliage fed upon, partially or wholly stripped from the trees or appearing sparse and sickly........Defoliators, p. 75
   3. Insects found feeding on the roots.
      a. Bark gnawed by large black ants and dark, soft-bodied aphids sucking sap from wounds
      Carpenter ants and root aphids, p. 34
      b. Tunnels or borings under bark of larger roots
      Root bark beetles, p. 35

Key to Diagnosis of Insect Injury to Young Trees (Cont.)

B. Terminal shoots, laterals, or tips deformed or killed. Trees weakened or stunted but seldom killed (except seedlings and small saplings).

1. New or old twigs, branches, or succulent shoots killed. Insect tunnels or borings found under the bark.

a. Point of attack showing a small, reddish pitch tube with exudation of fine boring dust and pitch. Under the bark or in pith of twigs are found small egg tunnels of uniform width, free from packed boring dust, made by small brown beetles; and larval tunnels packed with fine borings made by small, white, curled, legless larvae
Twig beetles, p. 36

b. Point of attack on green stems showing a small, clear pitch globule. Tunnels under bark, nearly round, free from pitchy exudations, filled with coarse or powdery boring dust. Made by small, white, curled, legless grubs........Twig weevils, p. 39

(1) Borings scoring sapwood rather superficially; boring dust coarse; pupal cells lined with shredded wood fiber
Pissodes spp., p. 39

(2) Borings deep in wood; boring dust fine-grained and powdery; pupal cells oval and smooth.............*Magdalis* spp., p. 41

(3) Small, round open holes in bark and wood; pupal cells formed in pith or wood, without lining but plugged with fine borings .....*Cylindrocopturus* spp., p. 42

c. Point of attack not conspicuous. Tunnels under bark broadly oval or nearly flat and filled with boring dust. Made by slender white grubs with broad heads ....Twig borers, p. 46

d. Bark and wood of twigs conspicuously gnawed and girdled, causing death and breakage
Twig girdlers, p. 46

e. Resinous tunnels made by active caterpillars under bark or in the shoots; point of attack showing resinous exudation, with larval castings webbed together, or pitch nodule......Twig or tip moths, p. 48

(1) Large reddish- or brownish-green to dirty-white caterpillars (3/4 to 1 inch long at maturity), boring into cambium of branches, twigs, or cones. Entrance indicated by webbed larval castings, followed by exudation of pitch
Twig moths, *Dioryctria* spp., p. 48

(2) Yellow, brown, or reddish caterpillars, about 1/2 inch long at maturity, start feeding around bases of needle fascicles on terminal shoots, then bore into terminal buds and down into new growth. Work characterized by resinous exudation at point of attack and death of terminal bud and needles at apex of shoot
Pine tip moths, *Rhyacionia* spp., p. 50

(3) Small, pale brown, or reddish to white caterpillars (1/2 inch long when mature) feeding on twigs and branches at nodes or whorls of branches causing a

Key to Diagnosis of Insect Injury to Young Trees (Cont.)

round, dirty lump of pitch and frass to form at point of attack
Pitch nodule moths, *Petrova* spp., p. 52

(4) Small caterpillars, about 1/2 inch at maturity, bore through center of developing shoots causing them to wither, droop, and die. . Pine shoot moths, *Eucosma* spp., p. 52
Exoteleia spp., p. 52

(5) Slender, grayish-white caterpillars, about 3/8 inch long when mature, feeding on bark of trunk or branches at forks or points of injury, causing small exudation of resin mixed with frass and death of affected part
Bark moths, *Laspeyresia* spp., p. 53

2. Leaves and buds at tips of branches killed. Trees often defoliated. Little or no damage to bark or wood.
Bud moths, p. 54

3. Tips of branches appearing unhealthy, sickly, badly swollen and deformed, or killed. No borings under the bark or in buds.
   a. Succulent tips covered with small, soft-bodied insects, or stems covered with powdery, cottony incrustations or shell-like scales; trees dripping a sticky exudation; often covered with a black smut. . . . . .Sap-sucking insects, p. 55
   b. Terminal shoots or leaves enlarged, galled, or swollen . . . . .Gall makers, p. 68
   c. Twigs with dying and dead needle tufts; bark filled with resinous pockets containing small red maggots . . . . .Pitch midges, p. 70

INSECTS AFFECTING ROOTS

Very few insects have been found attacking the roots of young trees, but these few deserve mention.

CARPENTER ANTS AND ROOT APHIDS

Large black, or black and red, carpenter ants (*Camponotus* spp.) from ¼ to ½ inch long, commonly found building their nests in logs, stumps, and houses (see p. 206), have been found gnawing the outer bark and cambium of roots of young conifers so that colonies of aphids (*Cinara* spp.) can feed on the fresh wounds. This damage has caused the death of both planted and wild seedlings in various parts of the Pacific Northwest. *Camponotus herculeanus ligniperdus* var. *noveboracensis* (Fitch) has been found injuring and killing Douglas-fir and western hemlock reproduction at several places in western Washington. The most serious damage is done at the root collar of 4- to 8-year-old trees, although older trees also are attacked. In southeastern Oregon *Camponotus herculeanus* var. *modoc* Wheeler has been found doing similar damage to small white firs and tending aphids (*Cinara curvipes* (Patch)). These aphids have been found working on the bark of white-fir twigs in California and Oregon.

ROOT BARK BEETLES

A few bark beetles (Scolytidae) have been found apparently killing large seedlings through attack on the roots. Species of *Hylastes, Hylurgops,* and *Pseudohylesinus* have been found doing this type of damage (see p. 154).

INSECTS AFFECTING TWIGS, TERMINAL SHOOTS, AND BUDS

Injury to leaf buds, succulent terminal shoots, and growing tips may be caused by insects of a number of different groups, such as twig-boring caterpillars, twig weevils, twig beetles, roundheaded or flatheaded borers, or even pitch midges, aphids, and scale insects (fig. 11). Such insects show a decided preference for these

FIGURE 11.—Ponderosa pines that were young and thrifty but have been killed by scale insects.

tender, growing parts of the trees. The damage they do to the new growth of older trees is much less important than that done to young trees. In the normal forest this type of damage to native trees is rarely extensive enough to be serious, but on cut-over lands and in plantations it is frequently disastrous.

The seriousness of this type of damage is shown in the sand-hill plantations of the Nebraska National Forest. Two species of pine tip moths (*Rhyacionia* spp.), which were of little importance in their native habitat, found their way into these new isolated plantations. In the new environment, freed from their native

parasites and finding the newly planted trees nonresistant to their attacks, they caused serious damage.

The control of terminal-feeding insects often presents an extremely difficult problem. Spraying, dusting, hand picking of damaged shoots, and the fostering of parasites have been the methods of control most frequently tried. Now that DDT and other new insecticides are available, some of the terminal feeders can be effectively controlled through airplane spraying. The cambium-feeding insects can usually be controlled by felling and burning the infested material, and leaf-feeding forms can be controlled by spraying or dusting. Special methods adapted to the control of each group will be mentioned under later discussions.

TWIG BEETLES

The bark and pith of the smaller twigs, and branches of various coniferous and broadleaved forest trees, are frequently mined by the smaller species of bark beetles of the family Scolytidae. These small twig beetles are often very abundant in the branches and twigs of dead, dying, or recently felled trees and in the twigs of healthy trees in the vicinity of slashings. Usually they confine their attacks to the twigs of trees of various ages and are commonly referred to as "twig beetles."

FIGURE 12.—The Douglas-fir twig beetle (*Pityophthorus pseudotsugae*) and its work in mountain hemlock. Natural size.

The attack of the twig beetles on living trees (fig. 12) is indicated by a small pitch tube or the exudation of fine boring dust at the point of attack on the twig. Under this will be found small tunnels of uniform width, free from packed boring dust, which

are made by small brown to black beetles. From egg niches along the sides of the egg tunnels, larval mines extend under the bark. These are made by small, white, curled, legless larvae that leave fine, packed boring dust behind them. On many trees several egg tunnels start from a circular entrance chamber under the bark and run lengthwise of the stem.

This type of work may be done by members of several genera of bark beetles represented by hundreds of species, so only a few of the more common species can be mentioned here. Moreover, there is no well-defined dividing line between the species that work in twigs and those that work in the larger limbs, branches, and trunks. Some species may be found breeding in all these places; so, in addition to the species listed in this section, those described under the heading "Bark Beetles" (p. 129) should also be considered.

The control of twig beetles has never been attempted in western forests, as their damage is seldom serious enough to warrant control measures. If they are especially bad in plantations or on shade trees, pruning the infested branches and burning the twigs or spraying with DDT may be of some benefit.

PINE TWIG BEETLES

Many twig beetles work under the bark and in the pith of pine twigs and sometimes in larger branches, and even in the trunks. These species develop readily in slashings and broken twigs, and frequently cause the deaths of twigs and limbs on living trees. The twig beetles most frequently found attacking pines belong to the genera *Pityophthorus, Pityogenes, Myeloborus, Carphoborus, Orthotomicus,* and *Ips* (pp. 143-154).

The typical work of the *Pityophthorus* consists of a central nuptial chamber under the bark, from which radiate several egg galleries each occupied by a female beetle (fig. 13). Eggs are placed in large niches along the sides of these egg galleries, and the larvae, on hatching, work through the cambium of the twig and, on reaching full growth, pupate at the end of the larval mines, often in the wood or pith of small twigs. There are usually two or more generations of the beetles each year, the number varying with the locality. Over 100 species have been described from western pines. A few of the more common western species include *P. confinis* Lec., which attacks ponderosa, Jeffrey, and Coulter pines throughout the West; *P. nitidulus* (Mann.), found attacking spruce and pines along the Pacific coast from Alaska through California; *P. carmeli* Sw., which sometimes is very abundant and destructive to Monterey and other pines along the coast of California; *P. confertus* Sw., which is commonly found attacking lodgepole, ponderosa, and many other pines throughout the West; and *P. tuberculatus* Eichh., which is also widely distributed in range and hosts.

The species of *Myeloborus* construct their egg tunnels principally in the pith of pine twigs. The larvae bore into the wood, without making definite larval mines, and so destroy the interior of the twig as to cause its death. In general, their work is bene-

ficial in that the death and dropping of lateral branches leaves the trunk of the tree freer from knots. In some cases, however, they are injurious to small trees.

FIGURE 13.—Typical galleries of the pine twig beetle *Pityophthorus nitidulus*. Natural size.

FIR TWIG BEETLES

Twigs of Douglas-fir and the true firs are frequently attacked by several species and genera of twig bark beetles. These usually are secondary enemies, attacking dying or felled trees, but occasionally they have been found attacking small living trees in crowded stands. The most common species found in twigs belong to the genera *Pityophthorus, Pityokteines, Carphoborus, Cryphalus, Crypturgus, Pseudohylesinus,* and *Scolytus.*

Species of *Pityophthorus* and *Pityokteines* make a central nuptial chamber from which several egg galleries radiate. One of the most common species is *Pityophthorus pseudotsugae* Sw. (fig. 12). Another common species found attacking true firs is *Pityokteines elegans* Sw. The adults of both species are about 1/8 inch long, and the females have long, yellow hairs on the front of the head.

CEDAR TWIG BEETLES

Small twig beetles belonging to the genus *Phloeosinus* are commonly found working in the twigs and limbs of cedarlike trees, but they rarely are numerous enough to cause any appreciable damage. In the limbs and twigs of California incense cedar are found *P. hoppingi* Sw., *P. antennatus* Sw., *P. fulgens* Sw., and *P. vandykei* Sw. In the twigs of Alaska yellow cedar *P. keeni* Blkm. may be found. *P. chamberlini* Blkm. and *P. hoppingi* Sw. work in the twigs of Sierra juniper in California and Oregon while *P. hoferi* Blkm. attacks the twigs of various junipers in Utah, Colorado, Wyoming, Texas, New Mexico, and Arizona. *P. spinosus* Blkm. attacks Arizona cypress in Arizona and New Mexico.

In addition to breeding under the bark of twigs and branches, adults of the larger species of *Phloeosinus* have the feeding habit of nipping off the leaflets and of feeding by boring into the small twigs of various cedars and cypresses. This injury is frequently very severe in ornamentals and shade trees.

Larger species of *Phloeosinus* attacking the main trunk of various cedars, cypresses, and redwoods are discussed on page 167.

OTHER TWIG BEETLES

Most twig beetles attacking spruce and hemlock belong to the genera *Scolytus, Pityophthorus, Pseudohylesinus, Pityokteines,* or *Ips*. These are discussed on pages 163-166.

Broadleaved trees are attacked by various bark beetles, including many species of Micracinae. Many oak twig beetles belong to the genus *Pseudopityophthorus* (p. 169).

The **shrub bark beetle** (*Micracis hirtellus* Lec.) is a secondary species which mines the hard, dry wood of many flowering shrubs and broadleaved trees including willow, alder, madrone, and California laurel in California. The adults are dark reddish brown and about ⅛ inch long. They have been found boring into lead telephone cables.

TWIG WEEVILS

Twig weevils, belonging to the family Curculionidae, often cause serious damage to the terminals of young coniferous trees. The adult female weevil uses her long, curved beak to excavate a small pocket in the bark of the terminal shoot in which to place her eggs. The young larvae, on hatching, burrow beneath the bark and excavate winding tunnels between the bark and wood. On reaching full growth each constructs an oval cell, partly in the wood and partly in the bark, in which to pupate. Weevil work is distinguished from that of the twig moths in that there is little exudation of resin or pitch, and such as does occur is not mixed with webbing or larval castings to indicate the presence of the insects under the bark. The first conspicuous evidence of injury is the dying of the terminal shoot.

The three most important genera are *Pissodes, Magdalis,* and *Cylindrocopturus*. In the East **the white pine weevil** (*Pissodes strobi* (Peck)) is an important example of these insects. In the

Western States there are several species that do similar damage; though not yet of economic importance, they are almost sure to be so when second-growth stands and plantations are more widely established.

Proper silvicultural methods offer the best solution of the weevil problem. Where young trees are grown in dense stands, or under the shade of other trees, weevil injury may be negligible. If in handling young stands subject to weevil injury the shade of older trees can be provided until the young trees reach 25 feet in height, or if the young trees can be grown in dense stands until they have passed the susceptible period, the damage should be lessened. In plantations, where individual care can be given, some control can be obtained by cutting off the infested stems in May and September and burning them or storing them in wire cages of a mesh small enough to hold the beetles but large enough to allow the parasites to escape. Weevil populations have been controlled at the time of emergence and egg laying by airplane spraying with DDT, applied at the rate of 1 pound of DDT per gallon of fuel oil per acre.

The Sitka spruce weevil (*Pissodes sitchensis* Hopk.) is the insect most injurious to Sitka spruce reproduction in the Pacific Northwest. The small weevils attack and kill or seriously injure the terminal shoots of many young trees, causing a crook in the trunk or a forked and worthless tree. Trees from 2 to 8 inches in diameter and 5 to 25 feet high are most susceptible to attack. In some plantations the Sitka spruce weevil has been so prevalent that nearly all young trees have been weeviled. As a result, the planting of Sitka spruce has been largely discontinued in Oregon and Washington. The species is distributed throughout the range of Sitka spruce.

The adults are light to dark brown, oval-shaped beetles, about 3/16 inch long, with a prominent curved beak. Late in the spring and early in the summer the adults feed on the tender bark of the previous year's terminals and with their beaks make little cavities in which eggs are laid. The young larvae, which are white, legless, curled grubs, work down the stem, boring through the bark and into the wood. Upon reaching maturity they form in the wood or pith an oval cell lined with shredded wood fiber in which to pupate. There appears to be only one generation a year, but some of the insects transform in the fall of the year and others change and emerge the following spring. The winter is passed in all stages except the egg. Upon emergence the new adults do some feeding on the fresh bark of the terminal shoots and make numerous small feeding punctures, which later heal over with a bit of resin. No effort has been made to control this species.

Similar in habits and appearance to the above is the **Engelmann spruce weevil** (*Pissodes engelmanni* Hopk.). It works in the terminals of Engelmann spruce throughout this tree's range, in the Rocky Mountain region and the Pacific Northwest.

The lodgepole terminal weevil (*Pissodes terminalis* Hopk.) (*139*) mines through the pith of lodgepole pine terminals (fig. 14) and kills them down to the first whorl of branches. It is particu-

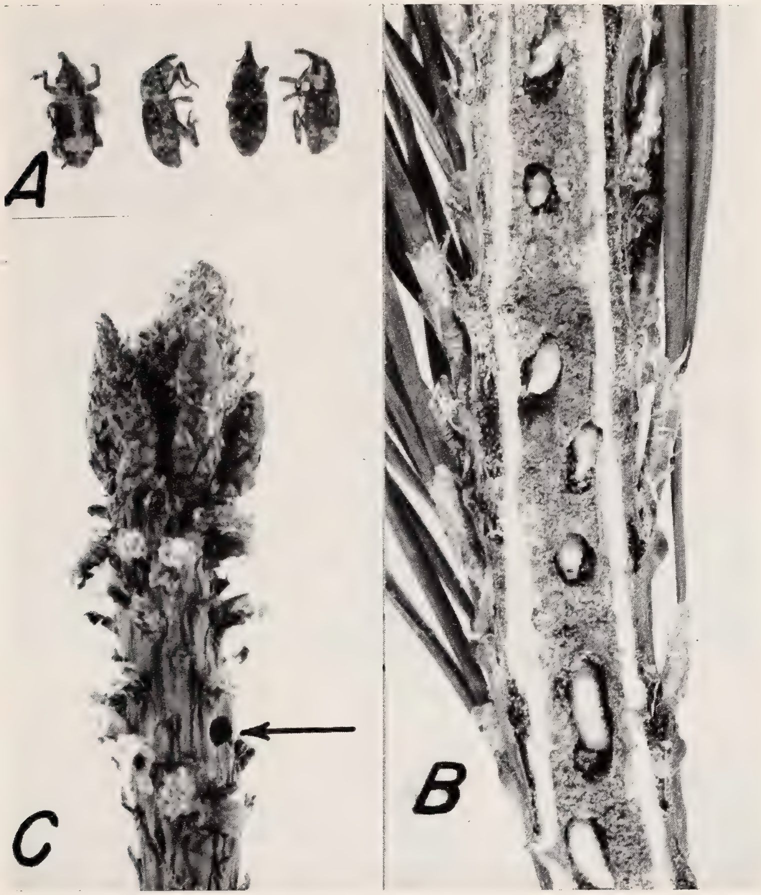

FIGURE 14.—The lodgepole terminal weevil (*Pissodes terminalis*): *A*, Adults; *B*, larvae and pupae in pith of terminal shoot; *C*, weeviled tip showing emergence hole. Greatly enlarged.

larly destructive in open-grown stands of young lodgepole pine in California.

Other species of *Pissodes* that may at times work in the terminals of young pines include *P. yosemite* Hopk., *P. schwarzi* Hopk., *P. radiatae* Hopk., and others that normally work at the base of saplings (see p. 176).

Certain species of the genus *Magdalis* are also twig borers during the larval period (fig. 15). The adults feed on the foliage and make punctures in the twigs of conifers and broadleaved trees, in which eggs are deposited. The grubs burrow beneath the bark and into the wood and cause the death of small branches and terminal twigs. The larvae are white, legless, and curled, and are practically indistinguishable from those of *Pissodes;* but the work is usually distinct in that *Magdalis* larvae tend to work into the wood more

FIGURE 15.—Pine twig weevils (*Magdalis lecontei*). Enlarged.

than do *Pissodes,* the larval borings are fine-grained and powdery instead of shredded, and the pupal cells are oval and smooth without the lining of shredded wood fiber. The adults are bright blue, green, or black, with prominent curved beaks. Western species include the following:

Species of *Magdalis*	*Hosts and distribution*
aenescens Lec.	Alder and apple. Alaska to California and eastward to Montana.
alutacea Lec.	Spruce. Colorado and other Western States.
cuneiformis Horn	Ponderosa and Jeffrey pine. Western States.
gentilis Lec.	Ponderosa and Jeffrey pine. California and Oregon.
gracilis Lec.	Alder, willow, and other broadleaved trees. California, Nevada, and New Mexico.
hispoides Lec.	Lodgepole and other pines. Maine to British Columbia, New Mexico, and California.
lecontei Horn	Ponderosa, Jeffrey, sugar, lodgepole, and other pines. Pacific States.

Small twig weevils of the genus *Cylindrocopturus* may be found killing terminal and lateral branches of young conifers and, in some cases, entire saplings. Many western pine species, true firs, and Douglas-fir are attacked. At times these weevils become exceedingly destructive to young trees in plantations and in dense stands of reproduction on burned areas. The adults are small, angular weevils 1/16 to 1/8 inch long, more or less covered with silvery-

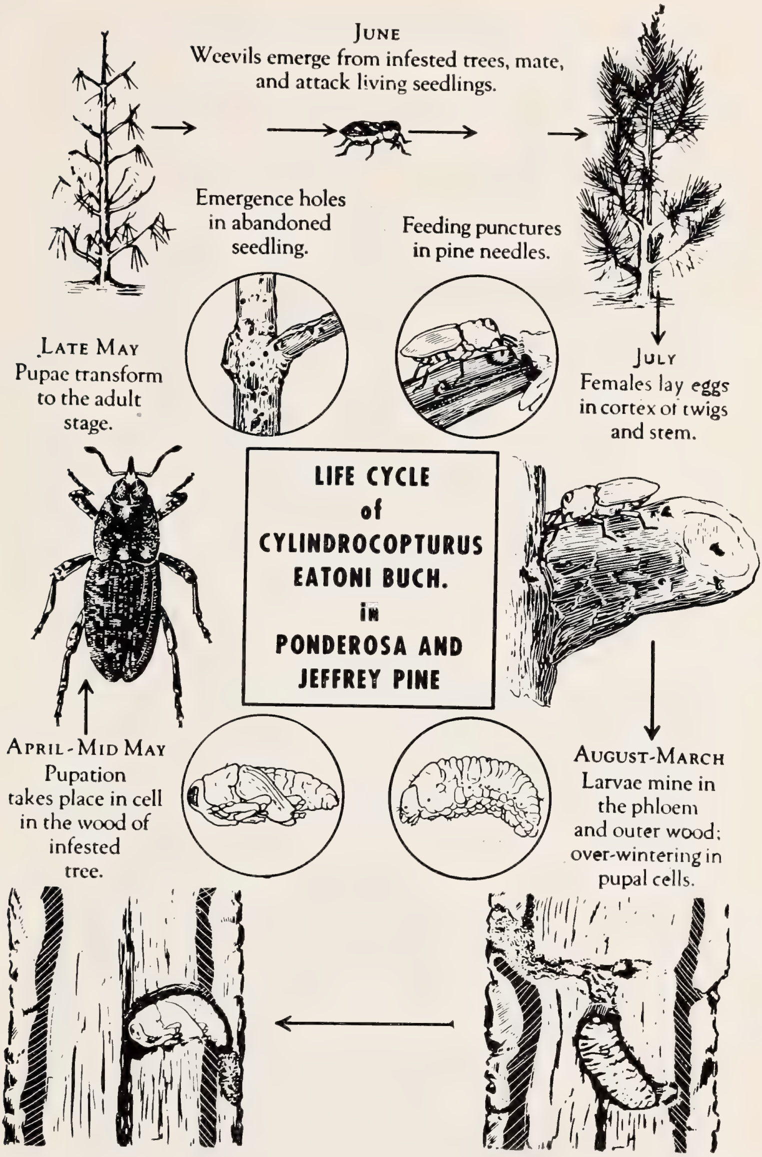

FIGURE 16.—Life cycle of the pine reproduction weevil (*Cylindrocopturus eatoni*) in ponderosa and Jeffrey pine.

white or bronze scales. In feeding they use their long beaks to puncture the needles and the thin bark on stems and twigs. The eggs are laid singly in punctures in the outer bark of living stems and twigs; the larvae feed through the outer and inner bark and when mature late in the summer, they bore into the wood and

pith, where they overwinter. Pupation occurs late the following spring, and the new adults emerge by boring through the outer bark to attack new trees. In older established forests damage is restricted to the very young trees and usually is not important. Control by burning the infested trees and by spraying living trees has been undertaken only for the protection of planted areas.

The pine reproduction weevil (*Cylindrocopturus eatoni* Buch.) (*46*) (fig. 16) probably is the most destructive species of this genus. During the period from 1938 to 1942 this weevil killed between 70 and 90 percent of the small ponderosa and Jeffrey pines planted in 1932–34 on one brushfield plantation in northeastern California. Since then it has made serious inroads into other plantations. The adults are extremely active insects. Soon after emergence late in May and in June they begin feeding by making noticeable punctures on the surface of the needles, and later they make similar punctures in the thin bark of the stems and branches. Eggs are deposited in punctures in the outer bark during June and early in July. The larvae start feeding in the cortex and, as they develop, extend their mines through the inner bark along the surface of the sapwood. This mining of the subcortical area usually causes the trees to die late in the summer or early in the fall. When mature, the larvae bore into the wood, and in small trees enter the pith, where they rest in their burrows from September until the following spring. Pupation occurs late in April and in May, and the new adults emerge in June. Airplane spraying with DDT in oil proved effective on one large brushfield plantation in northern California in 1947. Some individual pines appear to be capable of resisting the weevil, and recent studies conducted at the Institute of Forest Genetics in California indicate that certain hybrid pines that are resistant to weevil attack can be developed.

The Douglas-fir twig weevil (*Cylindrocopturus furnissi* Buch.) (*54*) (fig. 17), similar to *C. eatoni,* attacks and kills scattered small branches on open-grown Douglas-fir reproduction. These attacks may deform and retard the growth of the trees. Some trees less than 5 feet high may be killed outright; but by the time Douglas-firs have attained a height of 15 to 20 feet, they are no longer subject to appreciable damage. Adults emerge from the middle of June to the first week in August. After feeding for about 1 month, they deposit eggs in small punctures on stems and branches. The small larvae bore down to the surface of the wood, where they extend their feeding galleries. On approaching maturity, the larvae frequently bore through the wood into the pith. Larvae of all sizes overwinter, and pupation takes place the following spring, chiefly during May and June. There is one main generation and possibly a partial second each year. Natural control is obtained through host resistance, competition for food, and abundant parasitism. Artificial control has not been attempted.

There are many other described and undescribed species of *Cylindrocopturus* only two of which have been definitely associated with western forest trees.

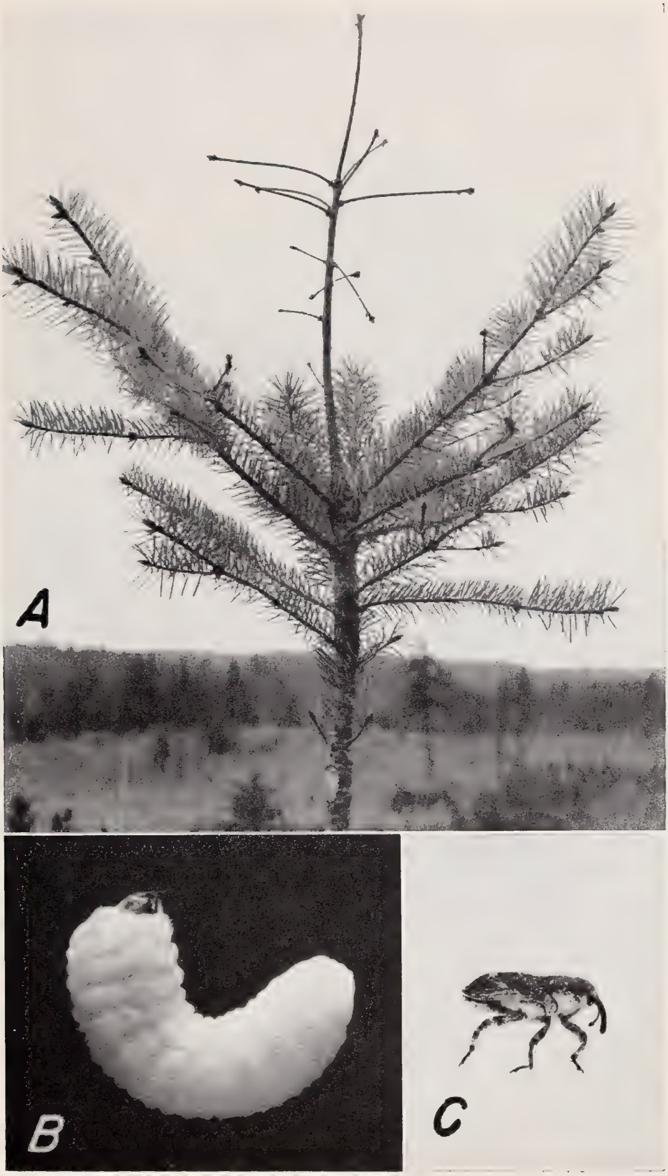

FIGURE 17.—The Douglas-fir twig weevil (*Cylindrocopturus furnissi*): *A*, Infested terminal shoot of Douglas-fir; *B*, larva, greatly enlarged; *C*, adult, × 6.

Species of *Cylindrocopturus*	*Hosts and distribution*
dehiscens (Fall)	Monterey and Bishop pines. California.
deleoni Buch.	Lodgepole pine. Idaho, Montana, and Wyoming.

TWIG BORERS AND GIRDLERS

A few bark- and wood-boring insects belonging to the families Buprestidae and Cerambycidae are of some importance as twig borers, or girdlers, in various forest, park, and shade trees (*67*).

Beetles of the family Buprestidae lay their eggs on the bark of twigs, and the larvae, referred to as flatheaded borers because of their horseshoe-nail appearance, work under the bark and into the wood, forming nearly flat tunnels filled with boring dust. The larvae are slender and white, without legs, and the enlarged forward segment of the body has horny plates on both the top and lower sides. Species that attack the twigs of coniferous trees usually belong to the genus *Anthaxia*, *Chrysophana*, *Chrysobothris*, or *Melanophila*. Many species of small flatheaded borers mine under the bark and kill the twigs of broadleaved trees. Some of the most striking work of this character is done by species of *Agrilus*, which make spiral girdles in the twigs of oak, birch, willow, and other broadleaved trees (fig. 18). Some of the western flatheaded twig borers and girdlers include the following:

FIGURE 18.—Spiral twig girdling is characteristic of *Agrilus*.

Species	*Hosts and distribution*
Agrilus angelicus Horn	Oak. California.
anxius Gory	Birch, poplar, and aspen. Entire West and British Columbia.
arbuti Fisher	Madrone. California and Oregon.
bilineatus (Web.)	Oak, chestnut, and beech. Eastern States and west into Colorado.
politus burkei Fisher	Alder. California, Oregon, Washington, Nevada and Wyoming.
politus politus (Say)	Willow, and maple. North America.

Species	Hosts and distribution
Anthaxia aeneogaster Cast.	Pines, true firs, cypress, redwood, oak, willow, and other forest and shade trees. Western States.
Chrysobothris femorata (Oliv.) (*24*)	Alder, ash, aspen, oak, poplar, willow, maple, beech, and many other hardwoods. Throughout the United States.
mali Horn (*24*)	Alder, ash, aspen, beech, maple, poplar, willow, and many other hardwoods. California; throughout the Western States.
nixa Horn	California incense cedar, cypress, and juniper. California, Oregon, and Nevada.
viridicyanea Horn	Juniper and cedar. California, Nevada, and Oregon.
Chrysophana placida (Lec.)	Pines, true firs, Douglas-fir, hemlock, and western redcedar. All Western States.

The adult long-horned beetles of some species of the family Cerambycidae girdle the limbs and twigs of various hardwoods and thus prepare them for the feeding of the larvae. These roundheaded borers are very similar to flatheaded borers, except that the body is usually thicker and has a horny plate only on the upper surface of the first enlarged segment. The larvae feed under the bark and through the deadwood of the killed twigs, forming broadly oval tunnels, which are filled with boring dust. The beetles that are most frequently involved in this type of damage are the following:

Species	Hosts and distribution
Methia juniperi Linsley	Juniper. Southern California.
Oncideres rhodosticta Bates (*100*)	Mesquite. Texas, New Mexico, and Arizona.
quercus Skinner (*100*)	Oak. Southern Arizona.
Styloxus bicolor (Champlain and Knull)	Juniper. Southern California, Arizona, and New Mexico.
californicus (Fall)	Oak. California and Oregon.

Other species of roundheaded borers that may be found in twigs and branches of western forest trees include the following:

Species	Hosts and distribution
Callidium californicum Casey	Juniper and California incense cedar. California, Nevada, Oregon, and Washington.
juniperi Fisher	Juniper. Arizona and New Mexico.
pseudotsugae Fisher	Douglas-fir. California and Oregon.
sempervirens Linsley	Redwood. California.
sequarium Fisher	Giant sequoia. California.
vancouverense Van D.	Douglas-fir. Pacific coast.
Lophopogonius crinitus (Lec.)	Oak. Pacific Coast States.
Neoclytus muricatulus (Kby.)	Douglas-fir, true fir, larch, spruce, and pines. Western States.
Oberea ferruginea Csy.	Willow. Colorado.
quadricallosa Lec.	Willow, Pacific Coast States.
Oeme costata Lec.	Ponderosa and pinyon. Colorado and Arizona.
Opsimus quadrilineatus (Mann.)	Spruce, Douglas-fir, true firs, hemlock, and pine. Pacific coast—California to Alaska.

Species	*Hosts and distribution*
Phymatodes hardyi (V. D.)	Douglas-fir, true firs. Pacific Coast States.
hirtellus (Lec.)	Ponderosa and Jeffrey pines. California and Oregon.
vulneratus (Lec.)	Bigleaf maple and ash. Pacific Coast States.
Poliaenus oregonus (Lec.)	True firs, Douglas-fir, and hemlock. Western States.
Saperda populnea (L.)	Poplar. North America.

TWIG MOTHS AND TIP MOTHS

The caterpillars of a large group of moths bore into and feed on the fresh, tender bark, and cambium layers of growing terminal and lateral shoots. Their feeding causes the deformation or death of these parts, causing the tree to be many-branched and poorly shaped, and sometimes kills it. Such damage is particularly serious in young plantations or cut-over lands where a second crop of straight, vigorous trees which will produce sound lumber in the shortest possible length of time is desired. Older trees are also attacked by these moths, but the injury to them is much less conspicuous and of little significance.

Damage of this type is caused principally by the caterpillars of moths belonging to the genera *Dioryctria* of the family Pyralidae and *Rhyacionia, Petrova, Eucosma,* and *Laspeyresia* of the family Olethreutidae.

The control of cambium-feeding twig and tip moths is very difficult, and as yet no completely satisfactory methods have been evolved. Spraying with an oil solution of DDT in May, when the eggs are hatching, has given good results, but the time of application is such an important consideration that the method should be used only with the advice of an expert. The use of other sprays is still in the experimental stage. Hand picking of the infested tips offers some hope of control on small valuable plantations that are isolated from sources of reinfestation.

TWIG MOTHS

While in the caterpillar stage the twig moths, belonging to the genus *Dioryctria,* bore into the cambium of trunk, branches, and twigs, or into the fresh green cones of pines, Douglas-fir, true firs, and spruce. The entrance to the tunnel is usually indicated by webbed larval castings. If the tree offers resistance to attack, a copious flow of pitch forms a resinous mass at the entrance. The damage results in serious injury or death of the parts affected or may even kill the tree.

The ponderosa twig moth (*Dioryctria ponderosae* Dyar) causes considerable injury in the plantations of the Nebraska National Forest, where it attacks ponderosa, Scotch, Austrian, jack, and Norway or red pines. Most of the trees attacked are under 8 inches in diameter, and the bole and tops are frequently girdled by the larval tunnels. Damage to Scotch and Austrian pines is particularly serious. This insect is probably distributed through most of the Western States, having been recorded from Nebraska, Montana, and northern California.

The adults are blackish-gray moths with a wing expanse of

nearly 1¼ inches. There are two narrow W-shaped bands extending across each forewing; the hind wings are dusky white. The moths appear from late in July to early in September and deposit eggs singly on the under side of bark scales, on trunk, or on branches. The small larvae hatch in 1 to 4 weeks, depending on the temperature, and spin small hibernacula under bark scales, in which they overwinter. The first evidence of attack appears the following spring in the form of a small quantity of larval castings on the bark surface, followed by an exudation of pitch from the entrance hole. The larvae feed in the cambium region and construct irregularly shaped galleries beneath the bark. Some of these are rounded cavities with short side galleries, while others extend several inches around the tree. The mature larvae are about 1 inch long, usually light brown, occasionally with a greenish tinge, and the bodies are marked with about six rows of small, dark-brown dots, or tubercles. These larvae spin white papery cocoons in the burrows, or sometimes in the dried-pitch mass near the surface, in which pupation takes place in July. The new adults leave the pupal skins in the cocoons and force their way through exit holes previously prepared by the larvae but concealed by flakes of bark or small webs.

Control was attempted by spraying the infested part of the stems with orthodichlorobenzene, diluted 1 to 5 with water, to which a small quantity of soap and linseed oil was added. The results were only partially satisfactory. Winter cutting and removal of the most heavily infested trees in the plantations resulted in a considerable reduction in the infestation. Control measures, however, are still in the experimental stage.

Dioryctria xanthoenobares Dyar is a golden-brown moth about ¾ inch long, which in the caterpillar stage attacks the twigs and cones of ponderosa and knobcone pines and possibly other pines. The caterpillar is pinkish and about 1 inch long when full grown. It is known in California, Oregon, Washington, and Nebraska.

Dioryctria abietella D. & S. is a gray moth about ¾ inch long. The reddish caterpillars feed in the twigs and cones of pines, firs, Douglas-fir, and spruce in all the Western States. There appear to be two annual generations. (See p. 22.)

The Zimmerman pine moth (*Dioryctria zimmermani* (Grote)) (*Pinipestis*) is a medium-sized light- to reddish-gray moth with a wing expanse of 1 to 1½ inches and marked with zigzag dark and lighter lines. The larvae are about ¾ inch long when full grown and range in color from a dirty white through reddish yellow to green. This pine moth appears to be distributed throughout the United States and attacks many species of pines. It is reported by Brunner (*17*) as being destructive to all coniferous trees, especially ponderosa pine, throughout the Pacific Northwest. Brunner credits the "spike top" of mature trees and the spike top, stunting, and destruction of smaller trees, to the work of this insect. However, its importance has probably been greatly overemphasized, as its damage is usually negligible in most localities.

The moths fly from May to September, but mostly in July. Eggs are deposited on the bark near wounds, and the newly hatched

larvae bore into terminals or branches killing them or patches of bark. The bark on some trees may be honeycombed with tunnels for several feet. The winter is passed as larvae or eggs, and moths emerge the following summer.

PINE TIP MOTHS

The pine tip moths, belonging to the genus *Rhyacionia,* may cause considerable damage to new leaders and shoots of young pine in localities of heavy infestation, especially in plantations or on cut-over lands where trees are openly spaced and growing on sunny exposures. Trees from seedling size up to a height of about 25 feet are the most susceptible to injury. The small moths are yellow, gray, or reddish brown. They lay their eggs on the pine needles, and the young caterpillars start feeding at the tips of shoots, burrowing into the buds and down into the new growth. Their work is characterized by a resinous exudation at the point of attack, but they do not form a pitch nodule on the stem. Though trees are seldom killed, they are often deformed or forked, and height growth is retarded. Several species have been described from the Western States, where they normally work on the tips of young forest trees. Two species are particularly destructive in the pine plantations of the Nebraska National Forest.

The western pine tip moth (*Rhyacionia frustrana bushnelli* (Busck) (*7, 40, 63, 154*) (fig. 19) causes some damage to seedlings and saplings in its native range in the Black Hills, the Lake States, and northwestern Nebraska, but has done serious damage where introduced in the isolated pine plantations of the Nebraska National Forest. In the ponderosa pine plantations of this forest about 90 percent of the leaders have been injured annually for many years by this tip moth. The adult moths are small, with a wing spread of about ½ inch. The front wings are mottled with yellowish gray and reddish brown. The larvae are yellowish and when full grown are nearly ½ inch long. A single generation occurs in the Black Hills, the moths flying late in May and early in June to lay their eggs on the pine needles, and the larvae feeding during June and July. In Nebraska two generations develop annually, the moths flying in April and May and again late in June and early in July. The winter is passed in the pupal stage in cocoons spun by the larvae in the litter or soil.

The southwestern pine tip moth (*Rhyacionia neomexicana* (Dyar)) has caused considerable injury to ponderosa pine seedlings and saplings at various places in the Southwest and is becoming a serious pest in the Nebraska National Forest plantations. It is known to occur in New Mexico, Arizona, southern and eastern Colorado, the Black Hills, and Nebraska. The moths measure about 1 inch in wing spread. The base of the front wings is dark gray and the outer third reddish orange. The reddish larvae, when full grown, are nearly ¾ inch long. There is but one generation annually. The moths fly in April and May in most localities, but in the Black Hills in the latter part of May and early in June. The full-grown larvae leave the tips during July and spin cocoons, usually in the bark crevices on the base of the tree below the litter.

Here they transform to pupae and pass the remainder of the season and the winter. Infested tips can be identified, after the larvae leave, by the dead, partially developed needles toward the apex of the shoot, and by the fact that this part of the shoot, and usually the buds, have been riddled by the larval burrows and crumble readily when dry.

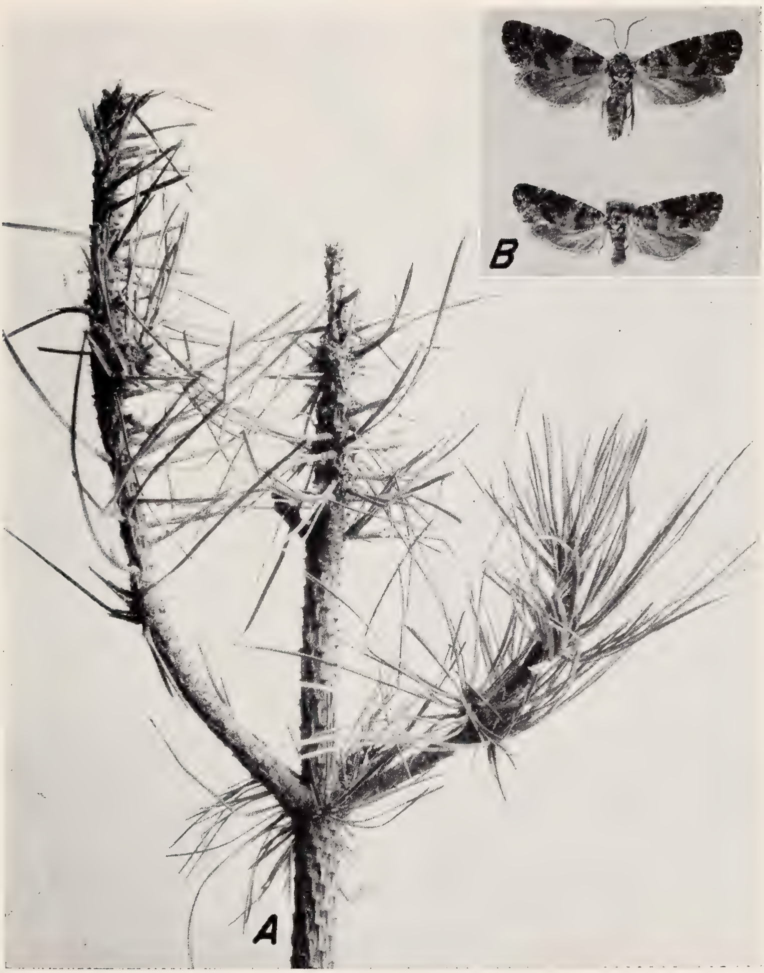

FIGURE 19.—The western pine tip moth (*Rhyacionia frustrana bushnelli*): *A*, Terminals of ponderosa pine damaged by caterpillars; *B*, adults, × 2.

Rhyacionia pasadenana (Kearf.) (*98*) is a silver-gray moth with reddish markings and a wing spread of ⅝ inch. The yellowish-orange caterpillars bore through the buds and new growth of Monterey, Bishop, and shore pine in the coastal section of California, causing a pitchy exudation and the deformation or

death of the terminal growth. *Rhyacionia zozana* (Kearf.) does similar work in the ponderosa and Jeffrey pines in the Sierra region of California. It is especially damaging to nursery stock and pine seedlings and saplings up to 6 feet in height growing in open stands unshaded by mature trees. *R. montana* (Busck) does similar injury to the buds and twigs of lodgepole pine in Idaho and Montana.

PITCH NODULE MOTHS

The pitch nodule moths, belonging to the genus *Petrova*, while in the caterpillar stage, bore into both the new and old growth of pine stems, twigs, and branches. Their work is characterized by a nodule or round dirty lump of pitch and frass, which is formed at the point of attack. They do not attack the buds but usually work at nodes or whorls of branches, and finally pupate within the pitch nodule. Trees are seldom, if ever, girdled by the larval channels but many are so badly weakened that the tops are broken by wind or snow. The moths are speckled with brown, yellow, or gray markings and have a wing expanse of about ¾ inch. The following species are found in the Western States:

Species of *Petrova*	*Hosts and distribution*
albicapitana (Busck)	Lodgepole pine. Idaho, Montana, Washington, and east to New England, also Canada.
burkeana (Kearf.)	Sitka and Engelmann spruce. Washington and Montana.
edemoidana (Dyar)	Ponderosa pine. Arizona and New Mexico.
luculentana (Hein.)	Ponderosa pine. Colorado.
metallica (Busck) (*fig. 20*)	Lodgepole and ponderosa pines. California to Montana.
monophylliana (Kearf.)	Singleleaf pinyon. California.
picicolana (Dyar)	Alpine and grand firs. Washington, Idaho, British Columbia, and California.
sabiniana (Kearf.)	Digger pine. California.

PINE SHOOT MOTHS

The caterpillars of the pine shoot moths, belonging to the genus *Eucosma* (*66*), bore through the pith of terminal shoots and leaders and into cones of various coniferous trees. Owing to the drooping of the dead lateral shoots the damage is often referred to as tip droop. The terminal leaders of young, thrifty trees are seldom killed, but the growth may be shortened. *Eucosma sonomana* Kearf. in the larval stage bores through the pith of the terminal twigs of ponderosa pine and Engelmann spruce. *E. bobana* Kearf. is an ochreous-colored moth with white spots on the forewings and a wing expanse of about 1 inch. The larvae have been found boring through the pith, cones, and seeds of ponderosa, Jeffrey, and knobcone pines in California and Oregon. *E. rescissoriana* Hein. is a dark brick-red moth with faint sprinklings of black scales, and a wing expanse of about ⅞ inch. The larvae feed through the pith and cones of lodgepole pine in California and Oregon.

The caterpillars of **the Monterey pine shoot moth** (*Exoteleia burkei* Keiff.) mine the developing shoots of Monterey pine, caus-

ing them to wither, droop, and die. The adult moth is grayish-brown with wings marked by three whitish bands edged with black tufts and bright orange and an expanse of 1/3 to 2/5 inch.

FIGURE 20.—The pitch nodule moth *Petrova metallica*: *A*, Pitch nodule opened to show larval mine; *B*, larva, × 3; *C*, pitch nodule with chrysalid protruding; *D*, adult moth, × 1.3; *E*, nodule opened to show larva surrounded by three parasite pupae and at right adult chalcid fly, parasite of larvae of the pitch nodule moth, × 4. (Drawings by Edmonston.)

BARK MOTHS

Some of the species of the genus *Laspeyresia* are cambium miners, working in the bark of various coniferous trees. *Laspeyresia inopiosa* Hein. works in the bark of lodgepole pine in Idaho. *L. laricana* Busck feeds in the cambium of larch and Douglas-fir. *L. leucobasis* Busck works in the bark of larch and Engelmann spruce. *L. populana* Busck breeds in the bark of *Populus trichocarpo* in Montana and Colorado.

The cypress twig moth (*Laspeyresia cupressana* (Kearf.)) (fig. 21) is a small coppery-brown moth with a wing expanse of about

FIGURE 21.—The cypress twig moth (*Laspeyresia cupressana*) and its work in Monterey cypress: *A*, Adult, × 2.25; *B*, eggs × 2; *C*, larva, × 3; *D*, pupa, × 3.75. (Drawings by Edmonston.)

5/8 inch. The caterpillars, which are slender and grayish-white, bore into fresh green cones and into the bark of trunks and limbs of Monterey cypress in California. Usually the attack is made at the forks of branches or at points of injury. It causes an exudation of resin and deforms or kills the affected part. In this work it probably plays a part secondary to that of a tree-killing bark disease, *Coryneum cardinale*.

BUD MOTHS

Frequently the tips of branches on young and older trees appear to be killed, but close examination reveals that the twigs are not injured and the damage is confined to the buds, developing needles, or terminal leaves. These are webbed together to form a case, within which a smooth, hairless, very active caterpillar is found. Work of this character is done by a group of bud moths, mostly belonging to the family Tortricidae, which are true leaf eaters and therefore defoliators (p. 102). Usually their damage is confined

to the leaves at the tips of branches, but during epidemics the older needles on the branches are also fed upon, and large forest areas may be completely defoliated and the trees killed. This group of bud moths, while it includes hundreds of species of only minor importance, also includes such conspicuous forest-tree defoliators as the spruce budworm, blackheaded budworm, and lodgepole pine needle tier.

SAP-SUCKING INSECTS

A large group of bugs, aphids, and scales belonging to the order Hemiptera, and the mites of the class Arachnida, closely related to insects, are equipped with slender beaks, which they insert into the tender leaves or shoots of plants and feed by sucking the juices from these succulent parts. These insects and mites are more important in the orchard and garden, or to shade trees, than they are in the forest. A few species, however, do noteworthy damage to small forest trees, and a few are important enemies of larger trees.

On shade and ornamental trees sucking insects can be controlled through the use of such contact sprays as lime-sulfur, miscible oils, or nicotine sulfate mixed with soap solution. Under forest conditions, however, the use of such sprays seldom is practicable, and so far no control work of this kind has been undertaken in western forests.

Key to Diagnosis of Sap-Sucking Insect Injury

A. Trees appearing sickly, leaves or stems not chewed but yellowing or covered with small incrustations, scales, powdery or cottony tufts, or small, soft-bodied insects. Trees frequently dripping with sticky exudation or covered with black smut.
  1. Trees dripping with sticky exudation, black smut usually abundant.
    (a) Colonies of small, soft-bodied, pear-shaped, or globular bugs, usually with two cornicles or protuberances on rear of abdomen, appearing on leaves or tender stems.............Aphids, p. 56
    (b) Small circular, oval or elongated shells or scales on leaves or twigs.....................Scales, p. 62
  2. Trees with white encrustations of cottony wax on leaves, twig or bark. Black smut often abundant *Chermes* or scales, pp. 58, 62
  3. Leaves sickly or yellowing in spots; little or no sticky exudation or black smut present.
    (a) Small tufts of cottony wax on under sides of leaves or stems........*Chermes* or scales, pp. 58, 62
    (b) Small, globular, dark-brown or black insects hidden in crevices of bark, in needle fascicles, or on needles................*Matsucoccus* spp., p. 64
    (c) Globules of spittle on stems or needles ..Spittlebugs, p. 66
    (d) Leaves covered with fine, nearly invisible webs or silvery coating...................Spider mites, p. 67

B. Trees appearing in fairly good health but leaves or stems badly stunted, galled, or swollen; sometimes with queer protuberances.
  1. Cone-shaped galls on terminal twigs of spruce...*Chermes*, p. 58
  2. Swollen twigs or galled bark covered with white incrustations ....*Chermes* and *Pineus*, pp. 58, 61
  3. Galls at base of pine needles causing premature shedding Pine bud mite, p. 69

APHIDS

Aphids are small, delicate, soft-bodied insects with pear-shaped or globular bodies and long legs. They range from almost colorless translucent to greenish or almost black. As a rule they are without protective covering and often occur in dense colonies on leaves or tender terminals of trees (*47*).

The aphids exude quantities of honeydew, which drips over the leaves and onto the ground beneath. This is a favorite food of ants, which cultivate and tend the aphids for it, and for this reason the aphids are often referred to as ant cows. The honeydew also becomes a fertile medium for the growth of a black smut that covers the leaves, causing the trees to appear as if they had been sprayed with crude oil. Shade and ornamental trees are rendered particularly unsightly, besides being weakened by the aphid feeding; and forest trees are sometimes so weakened that after a season or two they die from the injury.

Aphids are remarkable because of their peculiar manner of development and the difference in the mode of reproduction of separate generations of the same species. They reproduce both sexually and also without mating, and both winged and wingless forms occur. The number of generations of aphids may range from one to several in a single season, with more or less overlapping.

On shade and ornamental trees the aphids can be controlled by spraying, when they are first observed, with 4 or 5 pounds of fish-oil soap in 20 gallons of water, or with ½ pint of nicotine sulfate in 50 gallons of water to which 2 pounds of soap has been added. Crude-oil emulsion and commercial lime-sulfur are used as dormant sprays to kill the eggs. They are applied in the spring, about the time the buds begin to swell.

The spruce aphid (*Neomyzaphis abietina* (Wlkr.)) is by far the most destructive member of this group of sap-sucking insects that attack forest trees in the West. It has killed millions of board feet of Sitka spruce along the tidelands of the Oregon and Washington coast (fig. 22) and the Columbia River, and has caused considerable damage to this conifer on the better inland sites. The wingless aphids occur early in the summer on the old needles. These insects are dull green and range in size from very minute when young to about 3/16 inch in length when full grown. Apparently this insect has an alternate host, as it disappears from the Sitka spruce in midsummer only to reappear again the next spring. On shade and ornamental trees the pest can be controlled by spraying with such contact insecticides as nicotine sulfate, miscible oil, or lime-sulfur.

The Monterey pine aphid (*Essigella californica* Essig) is a small, light-green, pear-shaped insect about ⅛ inch in length and with very long hind legs. It is reported as feeding on the needles of Monterey and ponderosa pines and Douglas-fir in California and Oregon. *Schizolachnus piniradiatae* Davidson is a dark-green aphid, much smaller than the last named, and is covered with a cottony wax. This species attacks the needles of Monterey and other pines in central California. *S. tomentosus* DeG. is a yellow

FIGURE 22.—Sitka spruce along the Washington coast killed by the spruce aphid (*Neomyzaphis abietina*).

to brownish-black species, which lives on the needles of ponderosa pine in Colorado. Many kinds of aphids infest the leaves of various broad-leaved forest trees, but these are of little importance to forestry.

Large, long-legged, dark-colored aphids with naked bodies or lightly covered with a powdery wax belong to the genus *Cinara*. They are frequently found feeding on the terminal twigs of coniferous trees, where they insert their beaks through the tender bark. The copious flow of honeydew causes a dense smutting of the trees, sometimes making them appear as if they had been sprayed with creosote. At times the work of these aphids causes considerable injury. More than 35 species are recorded from the Western States.

Dirty-white, waxy encrustations on the bark of trunk, limbs, and twigs; white, cottony tufts on needles and twigs; and cone-

shaped or knoblike galls on the tips of twigs and branches are characteristic of the work of **bark gall aphids** belonging to the genera *Chermes* and *Pineus* (*1*). The bark-feeding forms are seriously destructive to certain coniferous trees, particularly spruce, fir, hemlock, and pine, and may bring about the death of heavily infested trees. Cone-shaped galls, which form on the twigs of spruce, frequently kill terminals but rarely endanger the life of these trees and are of little importance under forest conditions. On seedlings and saplings in nursery or plantation and on ornamental trees the formation of these galls is of some consequence, because they kill the tips of branches and tend to stunt and deform the trees.

Many of these gall-making species have an alternate host upon which they appear in a different form. One alternate form, frequently seen on pines, Douglas-fir, fir, and hemlock, appears as a dirty-white wax on the bark of twigs, limbs, and trunk. Another form appears as small tufts of cottony wax on the needles of Douglas-fir. Usually these bark and leaf-feeding forms exude a honeydew upon which a black smut grows, and accumulations of this smut make trees very unsightly.

Control of these aphids may be obtained by spraying early in the spring, when the young begin to colonize on new growth, with a spray composed of 6 gallons of miscible oil and 1 quart of 40 percent nicotine sulfate to 200 gallons of water. In nursery and plantation and on ornamental trees some control of the gall-making form can be obtained by cutting and burning the green galls before the insects emerge in the spring.

The Cooley spruce gall aphid (*Chermes cooleyi* Gill.) is the species most frequently responsible for the formation of cone-shaped galls on terminal twigs of blue, (fig. 23) Engelmann, and Sitka spruces in the West. Two or more other species do similar damage. The galls are from 1 to 2 inches long, light green to dark purple, and are formed by the growing together of the basal portion of the needles so as to form chambers between the base of the needles and the stem. These chambers, which are not communicating, usually contain from 3 to 30 small wingless insects covered with a white waxy coating. The galls turn brown, dry, and hard on the trees after the insects have escaped, and they may persist for many years.

On Douglas-fir these gall lice appear as small cottony tufts on the underside of the needles. Their feeding punctures cause the needles to turn yellow in spots. Sometimes the damage is so severe as to cause a browning and premature shedding of the foliage.

The seasonal history is very complicated. The form found on the Douglas-fir needles during the winter represents hibernating females, or stem mothers. These lay eggs early in the spring, and the young, which settle on the tender foliage and feed, later mature into winged and wingless females. The wingless forms deposit eggs, which hatch later into females that will hibernate, while the winged females migrate to the spruce and lay eggs at the base of the needles. The young hatching from these eggs cause the formation of the cone-shaped galls. About the middle of July the forms

FIGURE 23.—Old vacated gall of the Cooley spruce gall aphid (*Chermes cooleyi*) on blue spruce.

in the galls become full-grown, winged migrants, which return to the Douglas-fir to lay eggs that also produce hibernating females. Altogether there are five stages or forms in which *Chermes* appear during different periods of their development.

The species is distributed from British Columbia to California and eastward into Idaho, Montana, Wyoming, and Colorado.

Chermes oregonensis Annand appears as a small woolly louse on the twigs and base of larch needles in Oregon, Washington, and Montana, but does little damage.

The balsam woolly aphid (*Chermes piceae* (Ratz.)) (fig. 24) is a species introduced from northern Europe which has caused extensive damage in the Northeastern States and Canada. It has been reported from the San Francisco Bay area and the Willamette Valley on noble fir and grand fir (*1*). Since 1930 it has become exceedingly destructive to grand fir in western Oregon. On the

FIGURE 24.—Enlarged buds, or gout disease, of grand fir caused by the balsam woolly aphid (*Chermes piceae*).

main trunk it galls the bark and covers it with a dirty-white encrustation. On terminals it causes a swelling to form around the buds, leaving them in a depression and making the twigs appear to end in solid knobs, hence the name of "gout disease of fir." Infestations, if heavy, weaken trees, cause a thinning of foliage in the lower crown, progressing toward the top and finally killing the tree. Wherever spraying of tall trees is economically feasible, this aphid can be controlled with a 6-percent miscible-oil spray.

The hemlock chermes (*Chermes tsugae* (Annand)) (fig. 25) appears as a white, cottony encrustation on the bark and as white tufts on the needles of western hemlock in California, Oregon, Washington, and British Columbia. It seriously weakens and kills trees, particularly ornamentals in the Pacific Northwest.

FIGURE 25.—The hemlock chermes (*Chermes tsugae*) on twigs of western hemlock.

The woolly pine aphid (*Pineus pinifoliae* (Fitch)) is found in the Northwest from British Columbia to California and in Idaho, Montana, and Colorado, where it attacks blue, Engelmann, and Sitka spruces, and western white pine. On spruce it forms loose terminal cone-shaped galls somewhat similar to those of *Chermes cooleyi*, except that the poorly formed chambers are intercommunicating and contain only one or two young in each chamber, and when the insects emerge the galls flare open, and the scales drop from the twigs.

The alternate form attacks western white pine and is easily recognized by the waxy secretion that appears as a whitish-gray mold on the bark and needles. The attacked foliage is apt to be sparse and stunted; the needles fall prematurely, and the fascicles or bundle sheaths are left protruding from the limbs as short spurs. The damage is most frequently found on young white pines. In the last few years it has become a rather important enemy of white pine seedlings in eastern Washington, Idaho, and western Montana. The adults appear as little hemispherical, brown scales

$\frac{1}{16}$ inch in diameter, with a fringe of white hairs. The head and thorax are completely covered by this shield. The life history has not been thoroughly worked out, but is supposed to be as follows: Eggs are laid for the new generation early in the summer. These soon hatch and the young bark lice start sucking the juice from the white pine twigs. Some of these insects develop wings and fly to the spruce, where they construct the terminal cone-shaped galls. The others grow and reach the adult stage by the following spring.

Pineus boycei Annand makes similar galls on Engelmann spruce in Oregon and Montana. The needles with enlarged bases are pressed closely against the twigs and form intercommunicating chambers in which about 15 nymphs are found. The alternate host is not known.

Pineus borneri Annand feeds on the needles and twigs of Monterey pine in California.

Pineus coloradensis Gill. causes dense mats of dirty wax, covered with mold, to form on the twigs of various pines, including pondersosa, Jeffrey, lodgepole, pinyon, white, sugar, and singleleaf pine. It is found in Washington, Oregon, California, and Colorado.

Pineus similis Gill. forms cone-shaped galls on blue and Engelmann spruces in Colorado, Oregon, and British Columbia. The galls are shorter and thicker than those of *Chermes cooleyi,* and the chambers are intercommunicating. An alternate host is not known.

SCALE INSECTS

Scale insects (Coccidae) form one of the most abundant and variable groups of sap-sucking plant enemies (*47*). The young are mobile, small, and inconspicuous, but unlike most other insects, after they have become attached to a plant they lose all power of locomotion. They develop a hard epidermis, a thick waxy covering, or a round or oblong shell, and remain fixed in one position until they die. It is the female that causes all the injury to plants. The adult males often have wings, eyes, antennae, and legs, but no mouth parts and so cannot take food. They live only a short time and are rarely seen. A large number of species of scale insects infest nearly all forms of plant life, but only a few of those that feed on forest trees are of major importance.

Scale infestations on conifers, particularly those of the pine needle and black pine-leaf scales, are often associated with conditions where dust and smoke are found in the atmosphere. Heavy scale attacks on ponderosa pine trees bordering dusty roads have been frequently observed, as well as on trees exposed to air currents that carry the smoke from mills. The choking of stomata in the leaves by foreign particles probably renders them susceptible to these insects.

Scale insects are controlled through the use of contact sprays (*59*), such as miscible oils and distillate or petroleum emulsions, and in orchard work by fumigation. None of these methods are practical under forest conditions, but fortunately none of the scale insects attacking forest trees have become serious enough to call for control.

FIGURE 26.—The pine-needle scale (*Phenacaspis pinifoliae*).

The pine needle scale (*Phenacaspis pinifoliae* (Fitch)) (fig. 26) is probably the scale most commonly found on the foliage of western conifers. It occurs throughout the United States and Canada. In the West it attacks all species of pine and sometimes Douglas-fir, spruce, and cedar. Small trees, saplings, and poles, especially along dusty roads, are often so heavily infested that the foliage appears white. In some places trees have been killed by the attack. The mature scales are small, nearly pure white, elongated, and about ⅛ inch long. Eggs are laid in the fall and overwinter under the female scale. These hatch late in the spring, and the new scales become full grown by midsummer. An oil and nicotine spray will control this species if applied late in the spring, when the eggs are hatching.

The black pine leaf scale (*Nuculaspis californica* (Coleman)) is often associated with the pine-needle scale in its attack on various pines. It is reported to occur on Douglas-fir and hemlock and may

attack other conifers. Many young pines in California have been killed by this scale. It is distributed over most of North America. The mature scales are almost circular, $\frac{1}{16}$ inch in diameter, and yellowish brown to black. The young hatch early in the spring and summer and settle upon the new needles of the host. From one to three generations are produced during the year, and the winter is passed as half-grown scales.

A group of scale insects belonging to the genus *Matsucoccus* is sometimes found to be the cause of tipkilling, branch "flagging," stunting, or needle injury to pines. Larvae and adults are small, oval, yellow to brown, inconspicuous insects which are often extremely difficult to detect because they push themselves beneath the scale of needle fascicles or bury themselves under the bark of twigs and branches, taking on the color of their environment. Some species have caused serious injury to pines over extensive areas. No control methods have been developed.

The Prescott scale (*Matsucoccus vexillorum* Morrison) (*113, 114*) (fig. 27) has been found causing extensive killing of branches of ponderosa pine in Arizona, New Mexico, and Southwestern Colorado. The motile adult males and females emerge early in the spring. The females settle on twigs, mainly at the nodes of branches, where they lay eggs covering them with a fluffy white wax. Two stages of larvae develop late in the spring and in the summer; they feed beneath scales at the base of needles and in cracks and crevices of twigs, particularly around the first and second nodes. During the fall a third preadult stage develops and then overwinters under needle bracts as purplish, prune-shaped bodies. The life cycle is completed in 1 year.

Other species of *Matsucoccus* recorded from western pines include the following:

Species	*Hosts*
On needles—conspicuous:	
acalyptus Herbert (*104*)	Pinyon, singleleaf, and foxtail pines. California, Arizona, New Mexico, Utah, Colorado, and Idaho.
Within needle sheath at base of needle bundle:	
fasciculensis Herbert	Ponderosa, Jeffrey, and digger pines. California and Oregon.
degeneratus Morrison	Ponderosa pine. Arizona.
secretus Morrison	Ponderosa pine. California, Nevada, Arizona, New Mexico, and Colorado.
On bark at base of needle bundles, in axils of twigs and branches, and along small branches in crevices of bark:	
vexillorum Morrison	See above.
paucicicatrices Morrison (*111*)	Sugar, western white, and limber pines. California, Oregon, Montana, and Wyoming.
eduli Morrison	Pinyon. Arizona.
monophyllae McKenzie	Singleleaf pinyon. California.
In cracks and crevices of twigs and under heavy bark:	
bisetosus Morrison (*112*)	Ponderosa and Jeffrey pine. California and Oregon.
californicus Morrison	Ponderosa pine and Jeffrey pine. California and Arizona.

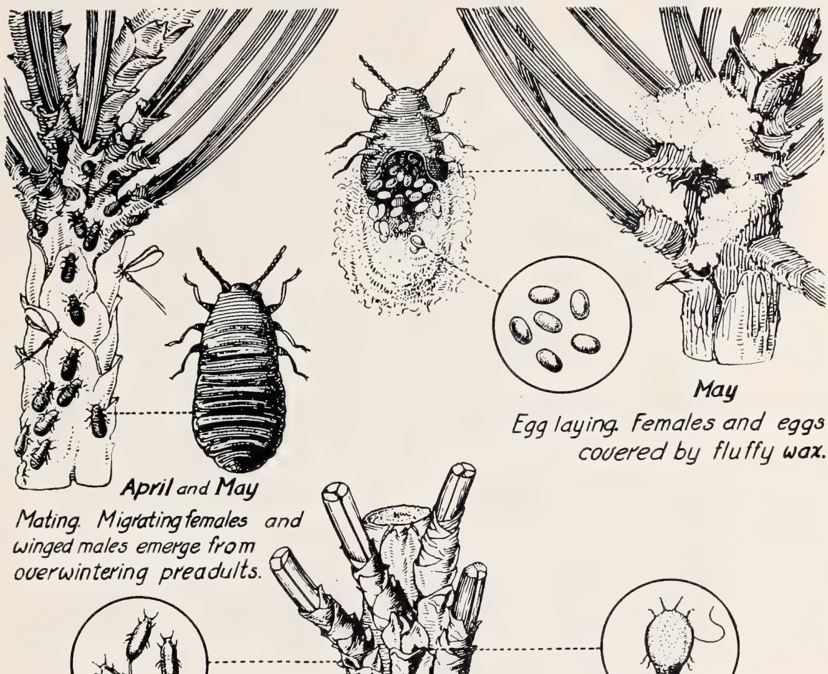

FIGURE 27.—Seasonal history of the Prescott scale (*Matsucoccus vexillorum*).

Closely related genera include the following:

Species	Hosts
Under bark scales or in cracks on trunk and limbs of hosts:	
Pityococcus ferrisi McKenzie	Sugar, western white, limber, and pinyon pine. California, Arizona, New Mexico, Texas, and Utah.
rugulosus McKenzie	Pinyon. Arizona.
In cells deep beneath bark of branches and trunk of host tree:	
Desmococcus captivus McKenzie	Singleleaf pinyon. California.
sedentarius McKenzie	Pinyon and singleleaf pinyon. Arizona.

Other common scales infesting western coniferous trees include the following:

Species	Hosts
Cryptaspidiotus shastae (Cole)	Giant sequoia, redwood, and cypress in California.
Diaspidiotus ehrhorni (Cole)	Douglas-fir and cypress in California.
Diaspis carueli Targ.	Cypress, California incense cedar, Port Orford cedar, and juniper. Throughout the United States and southern Canada.
Ehrhornia cupressi Ehrh. (*68*)	Monterey cypress and California incense cedar in California.
Physokermes insignicola Craw.	Monterey pine.
Toumeyella pinicola Ferris (fig. 28)	Monterey pine and other pines in California.
Xylococculus macrocarpae (Cole)	Monterey cypress and California incense cedar.

Some of the mealy-bugs also attack forest trees. These are small, soft-bodied bugs covered with a white powdery wax. They are represented by *Pseudococcus ryani* Coq. on cypress, California incense cedar, and redwood, and *P. sequoiae* Cole on redwood.

Species of scale attacking various broadleaved trees (*53*) are so numerous and most are of so little importance to forestry that they need not be mentioned here. **The oystershell scale** (*Lepidosaphes ulmi* (L.)) (*45*) is an exception, because it proved to be exceedingly destructive throughout the United States to a large number of broadleaved trees and in the West particularly to aspen, cottonwood, poplar, and willow. The mature scales are light to dark brown in color and shaped like a small elongated oyster. They tend to form solid crusts on twigs and limbs and often kill the entire tree. There is one generation annually, with young appearing in May and June. Crude-oil emulsions applied during the dormant season or a light summer oil and nicotine applied just after the young begin to crawl are most effective.

SPITTLEBUGS

Spittlebugs, of the family Cercopidae (*47*), sometimes do considerable injury to forest trees by sucking the juices from leaves and stems. They are called spittlebugs because of the mass of froth, resembling spittle, which covers odd-looking hopperlike in-

sects. *Aphrophora permutata* Uhl. sometimes injures Monterey pine and is also found on other pines, spruces, and firs in all the Western States. Other species of *Aphrophora* and *Clastoptera* are found on other forest trees in the West.

FIGURE 28.—The irregular pine scale (*Toumeyella pinicola*) on Monterey pine twigs. Slightly enlarged.

SPIDER MITES

Spider mites constitute a group of arthropods that have sap-sucking habits (*47*). These are not insects, but belong to the same group as spiders (Arachnidae). They have bodies divided into two segments instead of three, and have four pairs of legs instead of three. However, since they are closely related to insects and their work is similar, they are considered in this discussion.

These tiny spider mites have sharp-pointed, piercing mouth parts with which they suck the juices from leaves and tender stems of various plants, including many ornamental, shade, and forest trees. Leaves turn yellow and drop or are covered with silvery patches or webs. Peculiar galls are sometimes formed by these mites. Heavy attacks seriously weaken, and sometimes kill,

affected trees or render them susceptible to attack by other tree-killing insects.

Burke (*25*) rates them as the most important pests of shade, park, and ornamental trees in the Pacific Coast States. They are less important on forest trees under natural conditions. A few species have been reported as seriously injuring or killing native conifers, but their work is much more common on broadleaved trees.

Spider mites belonging to the genera *Tetranychus* and *Paratetranychus* are frequently the worst enemies of shade trees, especially in the warmer parts of the region and during long, dry, hot seasons. They suck the juices from leaves and cause spotting, fading, yellowing, or heavy leaf cast. Sometimes leaves are covered with silvery webs, or turn brown and rusty, as though scorched. Many species are found on broadleaved trees, and several are also found on conifers. Both sulfur dusts and wettable sulfur have given good control on shade trees when applied in the spring and summer when the temperature is high; or a dormant miscible oil spray may be used during the winter to kill the egg stages.

GALL MAKERS

A very large group of insects and mites have the strange ability to irritate various plants so as to produce a gall, swelling, or peculiar malformation (*51*). The common oak apple is a familiar example. Some galls take the form of large, globular protuberances, others take the appearance of buds or flowers, while some are simply an enlargement of the leaf or stem. These galls seldom are seriously harmful, however, and control measures are called for only where ornamental trees are made unsightly by such growths. On forest trees their presence can usually be ignored.

The cynipids, sawflies, gall midges, and gall aphids include most of the gall-forming insect species. Gall mites of the family Eriophyidae are also responsible for a large number of peculiarly shaped galls on broadleaved and other trees. Other important plant galls are formed by fungi and various parasitic plants.

On ornamental trees some of the gall-forming insects can be controlled by spraying at the proper season of the year, but for forest trees such treatment is impractical and seldom would be justified by the importance of gall damage.

There are innumerable types of galls on the various species of western forest trees (*50*), particularly on the broadleaved trees such as poplar and willow. Only a few of the more important gall insects on commercially important forest trees will be mentioned.

Key to Recognition of Some Important Insect Galls

A. Galls formed on coniferous trees.
  1. Galls on pines.
    a. Affecting pine needles.
      (1) Needles greatly enlarged or swollen at the base Gall midges, p. 70
      (2) Needles aborted or blistered within the sheaths, causing premature shedding....Pine bud mite, p. 69
    b. Affecting pine twigs.
      (1) Swollen twigs covered with gray, cottony secretions ....*Chermes,* p. 58
      (2) Twigs with dying and dead needle tufts ("flagging").
        aa. Bark filled with resinous pockets, or exuding small resinous masses, containing small red maggots Pitch midges, p. 70
        bb. Bark swollen or cracking open; small brown scales in bark crevices *Matsucoccus* spp., p. 64
  2. Galls on firs.
    a. Buds of grand fir badly swollen into "gouty" knobs *Chermes piceae,* p. 59
    b. Leaf swellings or apical bud galls enclosing pink or red maggots ....Gall midges, p. 70
  3. Galls on spruce.
    a. Cone-shaped galls on terminal twigs..........*Chermes,* p. 58
    b. Apical bud gall enclosing pink or red maggots Gall midges, p. 70
  4. Galls on juniper, or cedar.
    a. Slightly enlarged fruit and conical bud galls Gall midges, p. 70
    b. Prickly, burrlike or conical galls on twigs—Gall midges, p. 70

B. Galls formed on broadleaved trees inhabited by:
  Small, white, legless, apparently headless larvae..Cynipid wasps, p. 69
  Small pink or red maggots.........................Gall midges, p. 70
  Small bugs with cottony wax secretions ....Gall aphids, p. 58
  Microscopic eight-legged mites......................Gall mites, p. 68

The pine bud mite (*Phytoptus pini* Nal.) (Eriophyidae) is a very minute yellow blister or gall mite, which has been found causing injury to needles of Monterey, ponderosa, Jeffrey, digger, knobcone, and other pines in California and Oregon. It also is reported as causing stem gall in Europe. It feeds within the basal sheath of the needle cluster and causes a premature shedding of the needles and a weakening of the tree. A 10-percent miscible-oil spray has given fairly satisfactory control, but the removal of badly infested pine may at times be necessary. Many other species of eriophyid mites are found on both coniferous and broadleaved forest trees.

CYNIPID OR GALL WASPS

One group of small, four-winged, usually somber-colored yellow to brown or black, antlike wasps (Cynipidae) are responsible for the formation of a great variety of galls on the different parts of various forest trees, but particularly on the oaks. These galls may be large, round, and shiny, like the common oak apples, or very irregular in shape and spiny, or may consist of just a tiny swelling on leaf, twig, or root. The larvae that inhabit these galls are white,

legless, and without a distinct head. Over 200 species are described from various plants in the Western States, but only a few do appreciable damage.

GALL MIDGES

The gall midges belonging to the family Itonididae are responsible for the formation of a great variety of small galls on many different forest trees and plants. The adults are tiny pink flies resembling mosquitoes and are called midges. The larvae are small pink or red maggots, without legs or definite head, but with a dark "breastbone." Almost any part of the tree may be affected, but most galls are formed on the needles or leaves, in the cones or seeds, or in the bark of twigs. A few species on forest trees are of some economic importance.

The Monterey pine midge (*Thecodiplosis pini-radiatae* S. & M.) works at the base of the newly formed needles of Monterey pine and other pines in central California and causes them to become swollen and shortened (fig. 29). Sometimes heavily infested twigs are killed and the ornamental value of the trees is seriously impaired. Other species that produce swellings at the base of needles on pines include *Janetiella coloradensis* Felt on pines in Colorado and Utah, and *Thecodiplosis cockerelli* Felt on pinyon in Colorado.

Apical budlike swellings are formed on ponderosa pines in Colorado by *Contarinia coloradensis* Felt and *Dicrodiplosis gillettei* Felt.

Several of the juniper galls are caused by species of gall midges. *Walshomyia juniperina* Felt causes a slightly enlarged fruit or a purplish, apical bud gall with three or four diverging lobes on one-seed juniper, and *W. insignis* Felt makes an oval, apical bud gall on Rocky Mountain juniper. *Oligotrophus betheli* Felt forms reddish, apical, conical galls on Utah juniper. *Allomyia juniperi* Felt produces a prickly, burrlike bud gall with numerous short, straight leaves and none reflexed on Utah juniper. *Rhopalomyia sabinae* Felt attacks juniper in Colorado and Utah and produces thick-walled, purplish, apical bud galls which split open in four sections when the midges emerge.

Some of the pitch or gall midges attack the tender twigs or terminals of young trees and, by forming pitch pockets under the bark, either cause their death or the deformation of the wood. Their work can be recognized by the small pink or red larvae found imbedded in pitchy pockets or galls under the bark. The adults are frail, two-winged flies or midges resembling mosquitoes. Many of the western forms have not yet been named.

The bird's-eye pine midge (*Retinodiplosis* sp. near *inopsis* O. S.) is a common species in southern Oregon and California, where for many years it has killed the lateral tips of many young ponderosa pines (fig. 30). In some years this damage has been so severe as to deform and sometimes actually kill the trees. The damage is first noticeable very early in the summer, when the new lateral shoots fade, droop, and gradually turn yellow and die. On some trees nearly every new shoot is affected (*2*). On examination of

Figure 29.—*A*, Monterey pine needles galled by the Monterery pine midge (*Thecodiplosis pini-radiatae*); *B*, adult midge. Enlarged.

the dying tips the bark will be found to be pitted with small resinous pockets, in each of which are small bright-red maggots. If the pockets are not numerous enough to kill the terminal, the injury heals over, but for several years the annual rings are distorted into a peculiar whorl until the pocket is completely covered. This produces a defect in the grain of ponderosa pine lumber known as "bird's-eye pine" which actually enhances its value for finishing purposes.

The Monterey pine resin midge (*Retinodiplosis resinicoloides* Wms.) is another small pitch midge which inhabits the resin exudations of Monterey pine but apparently is not injurious to the trees.

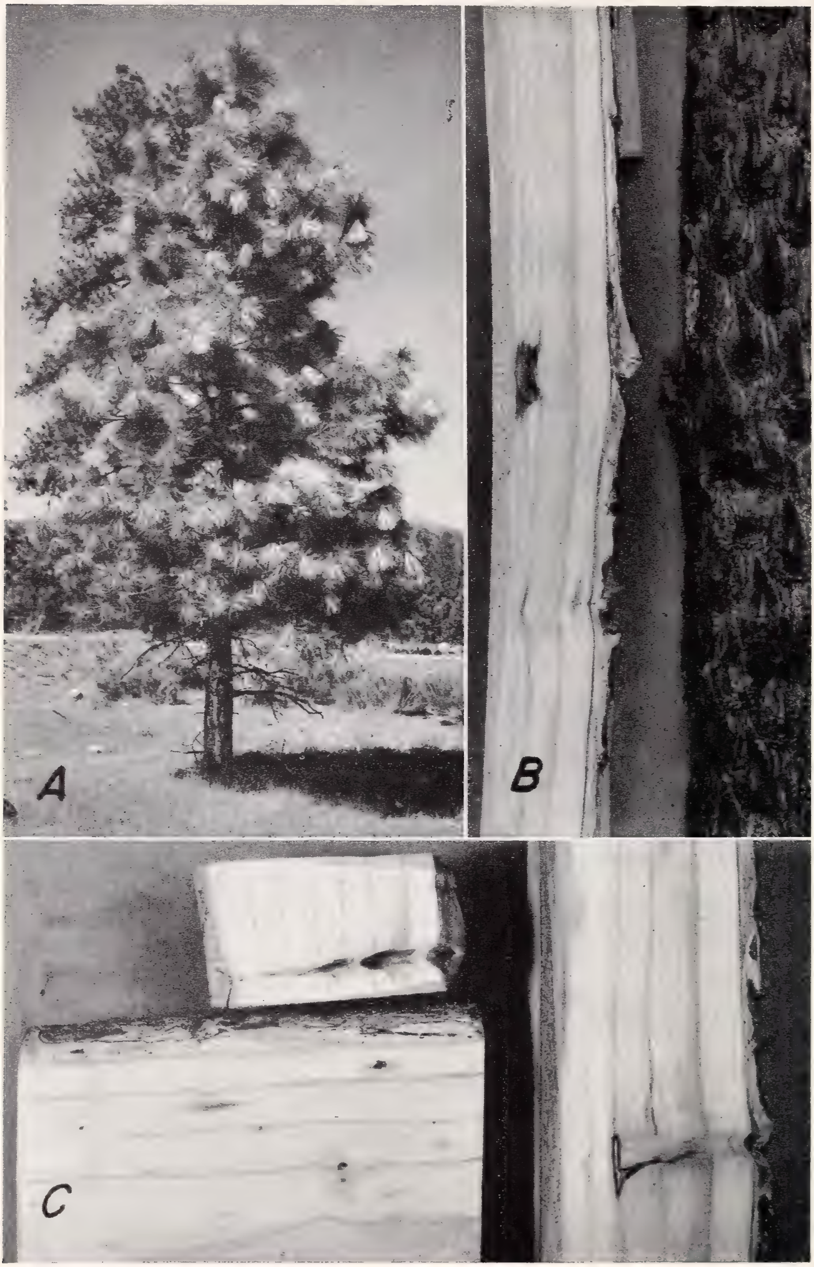

FIGURE 30.—Work of the bird's-eye pine midge (*Retinodiplosis* sp.): *A*, Twig tips killed by midge attack; *B*, pitch gall in cambium; *C*, bird's-eye effect in pine lumber.

FEEDERS ON THE INNER BARK OF YOUNG TREES

The most frequent damage to young trees by insects that feed on the inner bark is that suffered by intermediate or suppressed trees growing under crowded conditions or those weakened by drought, fire, or mechanical or other injury. Vigorous, young, dominant trees in the stand have a good chance to escape damage from these insects, except under conditions where they become epidemic. Usually the normal damage of this character in the virgin forests is of more benefit than otherwise, since it represents a natural thinning process and the release of the more dominant trees from competition. At times, however, such damage may become serious when outbreaks of bark beetles or other cambium- or root-feeding insects sweep through the young stands and kill a high percentage of thrifty as well as weakened individuals.

The insects which feed on the inner bark of trunk or roots of young trees are usually those which also feed on thin bark of older trees. These include certain groups of bark beetles, bark borers, and bark weevils. Since most of these insects do their greatest damage to older, mature trees, they will be discussed later under Miners in the Inner Bark and Phloem (p. 126).

Many species of bark beetles (Scolytidae) inflict their greatest damage on small or thin-barked trees. Many of these are rarely, if ever, primary and aggressive in their attacks on large trees, but may breed in windfalls, slash, or large trees that are dying or have been attacked first by other bark beetles. Breeding in such trees or felled material, they may emerge in large numbers and become very destructive to the small trees in the stand.

In pines, the pine engraver beetles of the genus *Ips* are the ones most frequently responsible for this type of damage. Less frequently species of *Pityogenes* or *Pityophthorus* are involved.

In young stands of Douglas-fir *Pseudohylesinus nebulosus* Lec. and *Scolytus unispinosus* Lec. frequently kill groups of small trees, particularly in the vicinity of slashings.

Small true firs are similarly affected by species of *Scolytus, Pseudohylesinus,* and *Pityokteines*. Young spruce and hemlock also may be killed by species of these and other genera.

Young redwoods, cedars, cypresses, junipers, and related cupressine trees are frequently killed by species of *Phloeosinus,* which breed in the trunks and limbs of dying or dead larger trees.

Although bark beetles (Scolytidae) are primarily enemies of large forest trees, a few species appear to be of importance in killing large seedlings and saplings through attack on the roots. Species of the genera *Hylastes, Hylurgops,* and *Pseudohylesinus* have been found doing this type of damage. Normally these are secondary bark beetles which breed in stumps and under the bark of trees killed by fire or insects, but they appear to be primary in attacking the roots of suppressed or weakened seedlings. The attacking beetles make entrance burrows at the ground line and construct winding galleries, which extend downward into the larger roots and are partly filled with frass. The larvae work through the cambium, away from the egg tunnels, and feed to-

gether without scoring the wood. Seedlings and saplings an inch or more in diameter are sometimes killed by the attacks.

DEFOLIATORS OF YOUNG TREES

Usually defoliating insects show no particular choice as to the age or size of tree they attack, and young trees in the forest may be fed on by almost any leaf-feeding form. However, some of the young trees in the stand are actually avoided by defoliating insects. This was particularly noticeable in hemlock looper outbreaks, where heavy defoliations ceased when stands of young growth were reached. On the other hand sometimes young trees are fed on in preference to older trees. This has been noted in some examples of spruce budworm attack on young Douglas-fir. Also, small trees may be fed on because of their closeness to the ground or their more tender succulent growth. For instance, young, low-growing pines have been seriously damaged by invasions of Mormon crickets and grasshoppers which, when in epidemic numbers, chew all green foliage within reach (p. 209).

Since the damage done by defoliators to mature forest trees is usually of greater importance than that done to young trees, this group of insects will be discussed in the following section.

INSECTS INJURIOUS TO MATURE FOREST TREES

The insects that prey on young forest trees and that may, during the formative years, cause serious injury through stunting, deforming, or halting growth are of little importance after the trees have reached maturity. The mature trees may still be fed upon by root-feeding or terminal-feeding insects, but such damage within reasonable limits can be borne without fatal consequences, and the small loss in growth on mature trees is of minor importance.

There are three principal groups of insects that cause the death of mature trees—(1) those that bore into the inner bark of the main trunk and cut off the supply of moisture and food; (2) those that feed on the leaves and cause severe defoliation; and (3) those that suck the juices from twigs or the main stem.

In many ways the defoliators are the most dangerous forest pests. They are primary and aggressive in their activities; that is, they attack healthy, vigorous trees as readily as undernourished, weakened ones (fig. 31). The injury does not always kill the tree, but often so weakens it that it becomes readily susceptible to bark-beetle attack. On the other hand, the miners of the inner bark usually direct their attack against trees previously weakened through drought, defoliation, fire, or some other cause. A few species of bark beetles are aggressive and primary in their attacks and tremendously destructive, but most species are decidedly secondary, attacking only trees that are already weakened or dying. A few sap-sucking insects, notably the spruce aphid and the balsam woolly aphid, are primary killers of mature trees.

It is true that the destruction of older, mature trees in the forest through attack by insects is more or less of a natural proc-

FIGURE 31.—Ponderosa pines severely defoliated by the pine butterfly.

ess. It is nature's way of disposing of the old decadent trees to make room for the younger, thriftier, growing individuals. Although a natural process, this destruction is most wasteful from the economic standpoint, since the old trees carry a large volume of high-grade lumber. The prevention of this type of damage, therefore, is an important phase of forest protection.

When more of our forests come under intensive management, and mature trees are utilized before they become decadent, much of the present loss in virgin forests will be avoided. Until such a time, the only alternative is the application of the control methods discussed at the end of this section.

Key to Recognition of Insect Injury to Mature Trees

A. Foliage fed on; partially or wholly stripped from trees; or turning yellow or red. Trees sickly or dying. No insects working on main trunk, branches, or roots ....Defoliators, p. 75

B. Terminal shoots, laterals, or tips deformed or killed. Remainder of tree appearing healthy..........................Twig feeders, p. 35

C. Entire tree, or a large part, sickly, dying, or dead; foliage fading, turning yellow or red. Bark and phloem of main trunk or roots mined by insects and killed ....Bark miners, p. 126

DEFOLIATORS

No other part of a forest tree offers nourishment to such a host of insects as do the leaves. Literally thousands of insect species feed on them in one way or another. Some mine within the needles, some skeletonize the leaves, and others eat the entire leaf tissues

or suck the juices. Trees can withstand a great deal of such feeding without being seriously affected, and some such insect work is going on more or less constantly. If the feeding is heavy, the growth of the tree is retarded. If a high percentage of the leaf surface is destroyed, the tree may die. The damage done to the forest by defoliators is difficult to estimate, since a large part of it involves only a loss of increment and not the death of trees. On the other hand, when epidemics of defoliators occur, their ability to destroy timber, especially coniferous timber, over large areas in a short time places them at the top of the list of destructive forest insects.

The extent to which a tree may be injured by defoliation will depend upon the tree species, whether the tree is evergreen or deciduous, its position within the stand, its general health, the insect species involved, and the time of year when the defoliation occurs. Since evergreens cannot replace their leaves as readily as deciduous trees, they are much more seriously injured by defoliation than those that normally shed their leaves each year. One year of severe defoliation may be enough to kill such trees as Douglas-fir, hemlock, and ponderosa pine. Alders and oaks, on the other hand, can sometimes withstand several seasons of defoliation without fatal injury. Dominant trees are more resistant than their suppressed neighbors, and vigorous trees have a better chance of resisting attacks than those weakened from one cause or another. Defoliators usually show little preference for weakened trees, as do many of the bark beetles, but are more likely to feed indiscriminately on whatever foliage of their favorite host happens to be at hand.

Outbreaks of defoliators are characteristically sporadic. For many years the forester may not observe a single specimen of some important leaf-feeding insect, and then, without warning, a sudden outbreak may occur and the forest may be swarmed with millions of caterpillars or slugs that devour everything in their path. Some defoliators, like the tent caterpillars, appear nearly every year at widely separated points in the forest. Others appear as major outbreaks at long intervals of time. Frequently, outbreaks go through a 3- to 5-year cycle. First, there is a preepidemic stage, in which the insect becomes unusually numerous. Then there is the epidemic stage, which usually lasts for 3 years, the first year showing evident damage, the second year a peak of damage, and the third year one of declining numbers but still with evident injury. Third, there is the post-epidemic period in which the insect returns to a normal or quiescent status. This decline in the epidemic may be brought about by natural control factors, such as an increase in parasitic enemies and disease, or through some climatic condition unfavorable to a continued activity of the defoliators.

The aim in control of native forest defoliators is not to attempt eradication but to protect forests from severe damage, either by preventing the build-up of epidemics by "catching them while they are small" or by reducing populations at the peak of epidemics to prevent heavy, concentrated feeding, which would be fatal to the

trees. In the protection of ornamental, park, and shade trees, rather intensive spray programs are justified in order to prevent damage. In protecting large timber stands, airplane spraying is now available as an effective weapon in defoliator control. The most difficult problem involved is one of deciding when an outbreak may become sufficiently damaging to justify the expense of airplane spraying, for most outbreaks subside of their own accord without reaching the stage of inflicting severe forest damage. Control methods are discussed on page 221.

The leaf-eating insects include all those leaf-feeding forms that have biting mouth parts and actually bite into and swallow their leafy food. They may be divided into three groups: (1) The leaf chewers, which feed externally upon and devour any part of the leaf; (2) the leaf skeletonizers, which eat out the green chlorophyll and leave only the network of veins and midribs; and (3) the leaf miners, which burrow through and feed between the surfaces of the leaves or needles. Some leaf-feeding insects are skeletonizers in their early stages and then devour all of the leaf as they become more mature. Some, when very young, mine the interior of the leaf and later eat all of it.

Outbreaks of leaf chewers do not always result in the death of the defoliated trees. For instance, large areas of hemlock forest in Washington, Canada, and Alaska have been badly defoliated by the black-headed budworm for two or more years in succession, and yet most of the trees have recovered. On the other hand, outbreaks of the hemlock looper, the pine butterfly, the Douglas-fir tussock moth, and even one recent outbreak of the black-headed budworm on Vancouver Island, British Columbia, have caused the death of billions of feet of standing timber, with a high percentage of the stand killed over hundreds of thousands of acres.

While the work of leaf feeders is easily detected in heavy defoliations, considerable injury often takes place before their activities are noticed. Since young caterpillars are more easily killed by poison than older ones, provided they can be reached, early detection and control are highly desirable.

As these leaf chewers actually swallow and digest their leafy food, the method of artificial control most frequently used in the past was to spray or dust the foliage with a stomach poison, such as one of the arsenicals. DDT and other new contact and stomach insecticides developed during World War II have now largely replaced the older chemicals, since these new materials are outstandingly lethal to most leaf chewers. Where small trees can be reached with ground sprayers, the application of these insecticides is a simple operation. Large forest areas can be treated satisfactorily only by airplane or helicopter. Application of insecticides from the air is discussed on page 223.

Insects comprising the group of leaf eaters are mostly either caterpillars (Lepidoptera) or sawflies (Hymenoptera), but a few beetles do similar work. Only those that have proved particularly injurious and with which the forester should become familiar are discussed here.

Key to Diagnosis of Injury from Defoliating Insects

A. Trees sickly, leaves not chewed but yellowing or covered with a sticky exudation or black smut............Sap-sucking insects, p. 55

B. Leaves stunted, galled, or swollen....................Gall makers, p. 68

C. Foliage appearing thin or sparse. Leaves chewed, mined, skeletonized, or stripped from trees.

1. Leaves chewed more or less indiscriminately or skeletonized. Defoliated part of tree not covered with silken webbing. Free feeders.

a. Work done by typical caterpillars with three pairs of true legs, four pairs of medium prolegs, and one pair of anal larvapods.

(1) On conifers.

aa. Stout, yellowish-green or brown, leathery caterpillars, 2 to 3 inches long, with short, dark hairs and seven or eight stout, branched spines on nearly every segment
Pandora moth, p. 83

(2) On broad-leaved trees and shrubs.

aa. Large, stout caterpillars with sparse, stout tubercles, and scattered spines.....Giant silk moths, p. 82

bb. Yellow and black caterpillars with branched spines
Brown day moth, p. 86

cc. Black caterpillars with fine, branched spines on each segment, middle row of spines bright yellow; on *Ceanothus*
California tortoise shell butterfly, p. 210

b. Work done by naked slugs with three pairs of true legs and six to eight pairs of prolegs; one end of body frequently held in midair when disturbed
Sawflies, p. 116

(1) On conifers.

aa. Larvae in nests of webbing and frass; on Monterey pine
Itycorsia spp., p. 120

bb. Larvae solitary or gregarious, not in nests of webbing and frass:
On pines......*Neodiprion* spp., p. 118
On western hemlock
Neodriprion tsugae, p. 120
On western larch
Anoplonyx and *Pristophora,* pp. 120, 122

(2) On broadleaved trees.......*Cimbex,* etc., p. 122

c. Work done by active grubs with three pairs of true legs, or by hard-shelled beetles.....Leaf beetles, p. 124

(1) On conifers, needles chewed to leave scalloped or sawtoothed edge:
On pines. *Dichelonyx* and *Scythropus,* p. 125
On white fir ....*Thricolepsis,* p. 125

(2) On broadleaved trees, leaves skeletonized or chewed; on alder, poplar, and willow
Altica, p. 123
Chrysomela, p. 124
Galerucella, p. 124

2. Leaves chewed, and defoliated part of tree covered with a light silken webbing; work of caterpillars with three pairs of true legs and less than six pairs of prolegs.

Key to Diagnosis of Injury from Defoliating Insects (Cont.)

a. On conifers.

(1) Caterpillars nearly naked with only fine hairs.

aa. Dark-green caterpillars 1 inch long, with fine, closely set hairs and two lateral white stripes on each side; on pines.....Pine butterfly, p. 80

bb. Caterpillars green to brown, with three pairs of true legs in front and two pairs of prolegs in the rear, travel with a looping motion; mostly on hemlock
Hemlock looper, p. 97

(2) Caterpillars very hairy.

aa. Caterpillars about 1 inch long, brightly marked with blue, red, or yellow spots and long pencils of hairs—2 in front and 1 in rear, and with distinct tufts of hairs like a toothbrush on their backs; on firs ....Tussock moths, p. 90

bb. Caterpillars of dull colors, black and yellow, clothed with long fur-like hairs; feeding in masses on terminal branches....Tiger moths, p. 87

b. On broadleaved trees.

(1) Caterpillars nearly naked with only fine hairs.

aa. Traveling with a looping motion, similar to hemlock looper; on oaks from Oregon to British Columbia
Oak looper, p. 100

bb. Olive-green caterpillars, about 1 inch long, with black and yellow stripes on top and sides, brown or red heads; California oaks
California oakworm, p. 89

(2) Caterpillars very hairy.

aa. Caterpillars brightly marked with long pencils of hairs in front and behind and toothbrush-like tufts of bristles on back
Tussock moths, p. 90

bb. Blackish caterpillars with row of nearly square, white blotches along the back, irregular white marks along the sides, and brown spines and longer, paler hairs; on poplar and willow....Satin moth, p. 93

3. Leaves chewed, and individual branches covered with dense webbing; on broad-leaved trees
Webworms and tent caterpillars, pp. 88, 94

a. Large, dense, conspicuous, silken tents formed at end of branches or in crotches; made by lightly haired caterpillars with blue, red, or yellow markings ....Tent caterpillars, p. 94

b. Loosely woven tents formed at ends of branches; made by yellowish-brown or gray caterpillars clothed with long, white hairs; arising from black and orange tubercles.......Fall webworm, p. 88

Key to Diagnosis of Injury from Defoliating Insects (Cont.)

4. Leaves rolled or tied together to form a protective covering for nearly naked caterpillars feeding within.
   - *a.* On conifers.
     - (1) New needles within opening buds fed upon and expanding foliage at tips of branches lightly webbed together and fed upon by nearly hairless caterpillars that wriggle violently backwards, or fall to the ground when disturbed
       Bud moths and budworms, p. 102
       - *aa.* On firs and spruce; caterpillars are dark brown with yellowish-green markings and pale warty tubercles on sides....Spruce budworm (*Choristoneura* spp.), p. 102
       - *bb.* On hemlock; caterpillars are bright green with black heads
         Black-headed budworm (*Acleris*), p. 105
       - *cc.* On spruce; yellowish to grayish-green caterpillars with brownish-yellow heads
         Spruce budmoth (*Zeiraphera*), p. 108
       - *dd.* On larch and fir; similar to the above
         Larch budmoth (*Zeiraphera*), p. 109
       - *ee.* On pines; mine needle fascicles, usually killing needles before they are half grown.....*Zelleria* spp., p. 112
     - (2) Needles mined and several drawn together to form a tube, lined with a white, closely woven web......Pine tube moth or needle tier, *Argyrotaenia*, p. 106
     - (3) Needles mined and several webbed together to form a mat of dead needles and frass.
       - *aa.* In spruce
         Spruce needle miner (*Taniva* spp.), p. 111
       - *bb.* In white fir
         Fir needle miner (*Epinotia* spp.), p. 112
       - *cc.* In cypress
         Cypress webber (*Epinotia* spp.), p. 113
   - *b.* On broadleaved trees...Leaf rollers and budmoths, p. 109
5. Foliage mined internally:
   - *a.* In coniferous needles...............Needle miners, p. 109
     - (1) Single pine needles mined; not webbed together
       Pine needle miners (*Recurvaria* spp.), p. 109
     - (2) Leaf scales and twiglets of cedarlike trees mined and webbed; without conspicuous frass; white cocoons on twigs
       Argyresthia spp., p. 112
   - *b.* In leaves of broadleaved trees and shrubs
     Leaf miners, p. 113

PINE BUTTERFLY

The pine butterfly (*Neophasia menapia* Feld.) (*48*) (fig. 32) is potentially one of the most dangerous enemies of ponderosa pine in the Northwestern States. One of the earliest recorded outbreaks occurred near Spokane, Wash., in 1882. Since that date several outbreaks have developed in the ponderosa pine

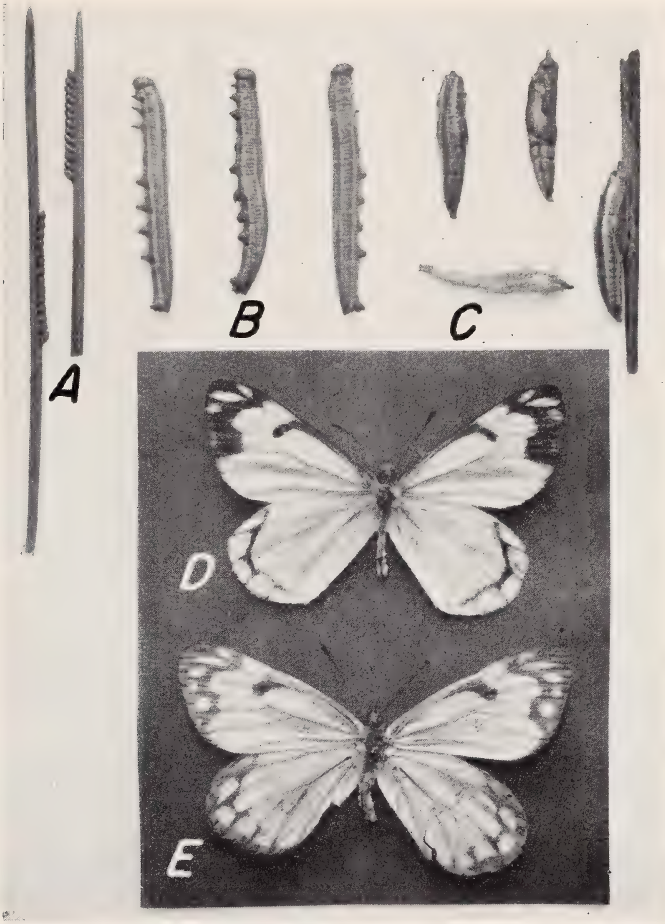

FIGURE 32.—The pine butterfly (*Neophasia menapia*): *A*, eggs; *B*, larvae; *C*, pupae; *D*, adult male; *E*, adult female. Slightly enlarged.

stands of Oregon, Washington, Idaho, and British Columbia. One of the worst of these was on the Yakima Indian Reservation, in Washington, 1893–95. Ponderosa pine over about 150,000 acres was affected, and from 20 to 90 percent of the stand was killed. The total loss amounted to nearly a billion board feet, and the effects of this outbreak are still evident. A more recent outbreak severely defoliated thousands of acres of ponderosa pine along the Little Salmon and Payette Rivers in Idaho in 1922 and 1923. Old, mature ponderosa pines are more susceptible to injury than the younger, thriftier trees. Western white pine and lodgepole pine, when in mixture with ponderosa pine, are also attacked Sometimes clouds of moths are seen hovering around the tops of Douglas-firs along the coast of Washington and British Columbia, but reports of damage to this tree have never been verified.

The adult is a white butterfly with black markings and a wing expanse of about $1\frac{3}{4}$ inches, resembling in general the common cabbage butterfly. The wings of the male are white except for some black markings on the tips. The forewings of the female have similar black markings, but have a distinct yellowish cast; the hind wings have the same yellowish cast but have a much heavier black marking than in the male. Many, but not all, females, have bright orange spots along the apical margin of the hind wings. These butterflies may be seen nearly every year flying about in pine and fir forests and hovering about the tops of trees.

Flight of the pine butterflies occurs in August, September, and October, and they lay emerald-green eggs on the needles a few hours after mating. These eggs are attached to needles near the tops of the trees and are laid in rows at an angle of 45° with from 5 to 20 eggs in each row, firmly cemented together (fig. 32). The winter is passed in the egg stage, and the eggs hatch the following June, or about the time the new needles begin to appear on ponderosa pine. The larvae, as they hatch, are very small, pale-green caterpillars, with shiny black heads. They feed in clusters, encircling the needle with their heads pointed toward the tip, forming a little ring of tiny black heads. Later on they feed singly and reach maturity by the latter part of July. When mature they are approximately 1 inch long, dark green, and covered with fine, closely set hairs, and with two white lateral stripes down each side. The anal shield is produced behind into two blunt, well-separated projections. The head is pale green and covered with short hairs. The full-grown larvae lower themselves to the ground by silken threads and then ascend low-growing vegetation to transform to pupae, forming chrysalids attached to shrubs, grasses, limbs, and tree trunks. From 15 to 20 days are spent in the pupal stage, and then the insects emerge as mature butterflies. Normally there is one generation a year.

Outbreaks of the pine butterfly seldom last for more than 3 or 4 years, for nature has provided a wasplike parasite (*Theronia fulvescens* Cress.), which was apparently responsible for the reduction of past outbreaks of this destructive pest. In the 1922 outbreak in central Idaho during the third year of the epidemic, over 90 percent of the caterpillars were parasitized by this beneficial insect, and the following season it was practically impossible to find a living caterpillar or butterfly within the defoliated areas. Before natural control becomes effective, however, a great deal of timber may be lost.

Artificial control by airplane spraying may prove useful in protecting the forests from heavy defoliation during the peak of the outbreak and until the defoliator is brought under control by natural means. If even half the foliage of a tree could be saved, the death of the tree would probably be prevented.

GIANT SILK MOTHS

The giant silk moths (Saturniidae) comprise a family of very large moths, the caterpillars of which are armed with spines or tubercles. Most of them spin dense silken cocoons in which to

pupate; hence their common name. As a forest pest the most important in this group is the pandora moth.

The pandora moth (*Coloradia pandora* Blake) (fig. 33) is an important defoliator of ponderosa pine in the forests of south-central Oregon, of Jeffrey pine in California east of the Sierra Nevada, and of lodgepole pine in central Colorado. This moth and closely allied species or varieties have been reported from nearly all Western States, where they feed upon various pines.

A destructive outbreak of the pandora moth occurred on the Klamath Indian Reservation of southern Oregon in 1918–25 (*131*). Thousands of acres of ponderosa pine forest were heavily defoliated, with an accompanying serious loss of timber. Lodgepole pine was also attacked when in mixture with ponderosa. Heavily defoliated trees died after 2 or 3 years. Others were greatly reduced in growth and recovered only after several years. The loss in growth throughout the defoliated area mounted to several million board feet. Even more serious was the bark-beetle damage that followed the defoliation and increased to alarming proportions in the weakened trees. Most severely injured were the pines growing on loose pumice soil, where the caterpillars could easily bury themselves for protection during pupation.

On the Arapaho National Forest in north central Colorado, an epidemic during the period 1937–40 defoliated lodgepole stands on an area of approximately 100,000 acres. This defoliation killed more than 4,000 trees and weakened many others (*161*).

Although some infestation may be found every few years, the records indicate that epidemics occur at fairly regular intervals of 20 to 30 years and continue in intensity for 6 to 8 years. During periods of abundance feeding may be fairly heavy without serious consequences. This is because the terminal buds are not eaten, and, since the insect has a 2-year life cycle and most of the feeding occurs in alternate years, the trees have an opportunity to recover. The more vigorous trees survive the attacks, and only during major outbreaks are losses likely to be heavy.

The adults are large, heavy-bodied, grayish-brown moths, with a wing expanse of 3 or 4 inches and a small dark spot near the center of each wing. The base and interior margins of the hind wings are clothed with pinkish hairs, which in the male shade to wine color. The males have large, feathery antennae, while the females have slender antennae and heavy bodies. During epidemics thousands of these large moths will be seen fluttering over the tree trunks and flying through the woods. The globular eggs, about $\frac{1}{10}$ inch long, are laid in clusters on the trunks or branches of trees or on litter on the ground. The newly hatched caterpillars are about $\frac{1}{4}$ inch long, with shiny black heads and black or brownish bodies covered with short, dark hairs. When mature, the caterpillars are from brown to yellowish green and $2\frac{1}{2}$ to 3 inches long, with each segment supporting a few stout branched spines.

The pandora moth requires 2 years to complete its life cycle. Adults appear the latter part of June and in July, and the eggs hatch in August. The young larvae crawl up the trees and during the early molts feed in groups on the new foliage. At the end of

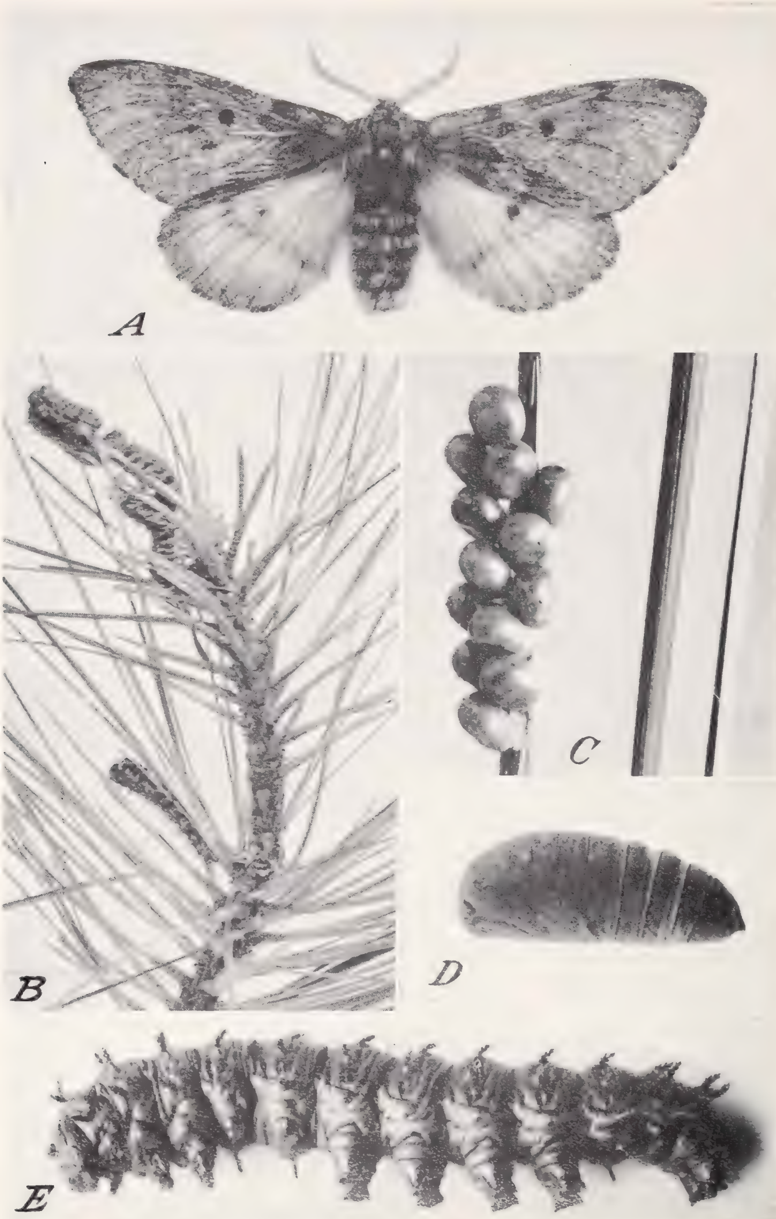

FIGURE 33.—The pandora moth (*Coloradia pandora*): *A*, Adult male, natural size; *B*, young larvae on pine needles; *C*, eggs, × 3; *D*, pupa; *E*, full-grown caterpillar, × 1.25.

the season they are about 1 inch long. These immature larvae spend the first winter hibernating in clusters at the base of the needles. They resume feeding the following spring, and the caterpillars reach full growth by the last of June. When mature, they crawl down the trees and enter the soil to a depth of 1 to 5 inches, where they form elliptical cells, sometimes sparsely lined with a silky material, in which they transform to the pupal stage. The pupae are dark reddish brown, from 1 to 1½ inches long, and about ½ inch wide. The pupal stage lasts a full year, and the moths are not ready to emerge until the following June and July.

An interesting sidelight on the economic importance of this insect is that the larvae or pupae form a delectable food for certain Indian tribes. The Mono Indians of California dig trenches around the infested trees and build smudge fires, which cause the caterpillars to drop to the ground in great numbers. They are caught in the trenches, killed, dried, and eaten cooked with vegetables to make a stew. The Klamath Indians in Oregon prefer the pupae, which, when dug from the ground and roasted or boiled, are considered a great delicacy.

Epidemics of the pandora moth are brought under control by a number of natural enemies. Probably the most important is a wilt disease that attacks them about the time they reach full growth and start to descend the trees. Once this disease becomes well established it runs rampant through the hordes of caterpillars, and very few of the insects escape. Ground squirrels and chipmunks dig up and destroy large quantities of pupae. Birds feed only sparingly on the caterpillars, which appear to be distasteful to most of them. Four or more species of insect parasites attack the caterpillars and dispose of many of them.

Now that DDT is available, this defoliator probably could be held in check by airplane spraying in the early spring immediately following resumption of larval feeding.

Light burning is a method of control that was tried by a private timber company on a large tract of privately owned land in southern Oregon. In the fall of 1922 fire was run through this tract while the pandora caterpillars were feeding. The smoke and heat caused them to drop to the ground, where they were destroyed. On account of the damage and danger in the use of fire, this method is of questionable benefit. The remedy may easily be "worse than the disease."

A closely related species, *Coloradia doris* Barnes, first described in 1900 from Colorado, became epidemic in 1938–39 on ponderosa pine near Osage, Wyo., and on the Harney National Forest in South Dakota. It also has been reported from Montana. The large caterpillars have long, branched spines on the first and second dorsal segments behind the head and on the last abdominal segment, as contrasted with pandora larvae which have short, stout spines on all segments. The adults have wings much less heavily scaled than pandora with the hind wings translucent and the discal spots oblong instead of round and not so prominent as in pandora.

Besides the pandora moth, other members of this family feed on broadleaved trees and shrubs.

The ceanothus silk moth (*Platysamia euryalus* (Bdv.)) (47) is a large, showy moth, densely clothed with reddish hairs and having white and black markings. It has a wing expanse of 4 to 5 inches. The large pale-green to blue caterpillars, with golden tubercles on the back and bluish tubercles on the sides, sometimes feed on willow, manzanita, and other shrubs. It is distributed throughout the Pacific Coast States and east to Wyoming. *P. gloveri* Strecker also feeds on maple, willow, and many other trees and shrubs. The caterpillars are 3 inches long when full grown, yellowish-green with black spines, and have two rows of tubercles on the back with black spots between them. It ranges through the Rocky Mountains and the Southwest. **The cecropia moth** (*P. cecropia* (L.)) is an eastern species which ranges west into Montana. The caterpillars are pea-green with a bluish tinge, with 4 large coral-red tubercles on the second and third thoracic segments and 15 yellow tubercles on the first to eighth abdominal segments. The cecropia moth feeds on a large number of forest trees, including ash, birch, maple, and willow.

The polyphemus moth (*Telea polyphemus* (Cram.)) (*47*) is a beautiful, large, yellow to reddish-brown moth with a wing expanse of 4 to 5 inches and clay-colored wing margins. Each forewing has a nearly round eyespot margined with yellow, and the hind wings have large eyespots margined with black and blue. The pale apple-green caterpillars have pale yellow lines on each side, and pale orange or golden tubercles arising from a red spot. This moth feeds on alder, madrone, maple, oak, poplar, willow, and other trees and shrubs. It ranges throughout the United States.

The Nevada buck moth (*Hemileuca nevadensis* Stretch) (*47*) is a large white or yellowish moth with a yellow, orange, or red tuft at the tip of the brown to black abdomen and a wingspread of nearly 3 inches. The large, spiny caterpillars feed gregariously on willow and poplar and sometimes are injurious. The species is distributed from California eastward into the Great Plains and throughout the Southwest. The caterpillars of **the buck moth** (*H. maia* (Drury)) are about 2½ inches long, dull brown to black, each segment having small yellowish dots and tufts of compound bristles arising from tubercles. These caterpillars feed on willow and oak in New Mexico, Colorado, and eastward. Caterpillars of *H. juno* Packard feed on willow, cottonwood, and poplar in the Southwest.

The brown day moth (*Pseudohazis eglanterina* (Bdv.)) is a showy yellow to orange-brown or purplish-pink moth with black markings and a wing expanse of 3 inches. The shiny, dark brown to black caterpillars, with reddish spots on the back and a narrow red line on each side, feed on willow, manzanita, and many other shrubs. It is distributed throughout the Rocky Mountain and Pacific Coast States.

TIGER MOTHS

The tiger moths (Arctiidae) are so named because of the contrasting colors shown by many. Some of the species are without markings, but most of them are very beautiful. The caterpillars are robust and very hairy, some of them being known as woolly bears. Most members of the family are important leaf feeders.

The silver-spotted halisidota (*Halisidota argentata* Pack.) (fig. 34) is a strikingly colored yellowish-brown moth with a wing spread of 1½ to 2 inches and a body covered with long yellow

FIGURE 34.—The silver-spotted halisidota (*Halisidota argentata*): *A*, Full-grown caterpillar; *B*, eggs on needles; *C*, adult male; *D*, adult female. All natural size.

hairs. The forewings are reddish brown with numerous distinct silvery-white spots. The hind wings are light tan to nearly white with a few brown marks near the outer margin. The moths emerge, fly, and mate during July and August, and deposit pea-green eggs in clusters on the twigs and needles of the host trees. As many as 325 eggs have been laid by one moth. The eggs hatch in about 2 weeks, and the small brown, hairy caterpillars feed in dense clusters on the needles of lateral branches, forming webs with masses of dead needles attached to the branches. Feeding continues during the fall, the larvae hibernate in the webs during the winter, then resume their gregarious feeding in the spring. Late in the spring, the two-thirds-grown caterpillars disperse and feed singly on the needles until mature. Full-grown caterpillars are about 1½ inches long, densely clothed with long brown-to-black brushlike, poisonous hairs. In June the mature caterpillars spin dirty-brown cocoons composed of silk and larval body hairs. They attach the cocoons to the needles, twigs, or trunks of the defoliated trees or to debris on the forest floor.

The principal host is Douglas-fir, but this insect also attacks true fir, Sitka spruce, shore pine, and occasionally other conifers. It is distributed from the Atlantic to the Pacific, and the western form is found throughout the Western States. This species would be seriously destructive were it not for its natural enemies, which annually take a heavy toll of the caterpillars. Therefore applied control measures are not likely to be necessary. The variety *H. argentata sobrina* Stretch feeds on Monterey pine in California.

Several closely related species of the genus *Halisidota* are also forest-tree leaf feeders. *H. ingens* Hy Edws. has dark-brown forewings with large white splotches; the hind wings are white, and the body is covered with buff-colored hairs. Its caterpillars feed on the needles of young ponderosa and pinyon in Colorado, Utah, New Mexico, and Arizona.

The spotted tussock moth (*Halisidota maculata* (Harr.)) has tan forewings with wavy brown splotches and a spread of about 1¾ inches. The hind wings and body are buff-colored. The caterpillars, about 1¼ inches long, are densely covered with black hairs, with a few white and yellow hairs intermixed and a wide belt of shorter, tufted black hairs in their middles. This species and its varieties are found in all the Western States feeding on willow, oak, maple, alder, poplar, and many other trees and shrubs.

The fall webworm (*Hyphantria cunea* (Drury)) is a common defoliator of broadleaved trees, such as madrone, alder, willow, cottonwood, and various other shade trees, fruit trees, and ornamentals, but it is of little importance to forestry. The caterpillars, an inch long when full grown, are pale yellow to brown, but appear grayish because of the long whitish hairs that arise from black and orange tubercles. They spin very large webs, within which they feed on the foliage. These tents often enclose an entire branch and are very conspicuous late in the summer. Feeding takes place from July 1 to September 15. Maturity is reached late in the fall, and the winter is passed as pupae in dark-brown cocoons on the ground or attached to the tree trunks. The following

spring the adult moths appear. These are nearly white, with a few black spots on the wings, orange markings on body and legs, and a wing expanse of 1¼ inches. A spotless form is called *H. textor* Harr.

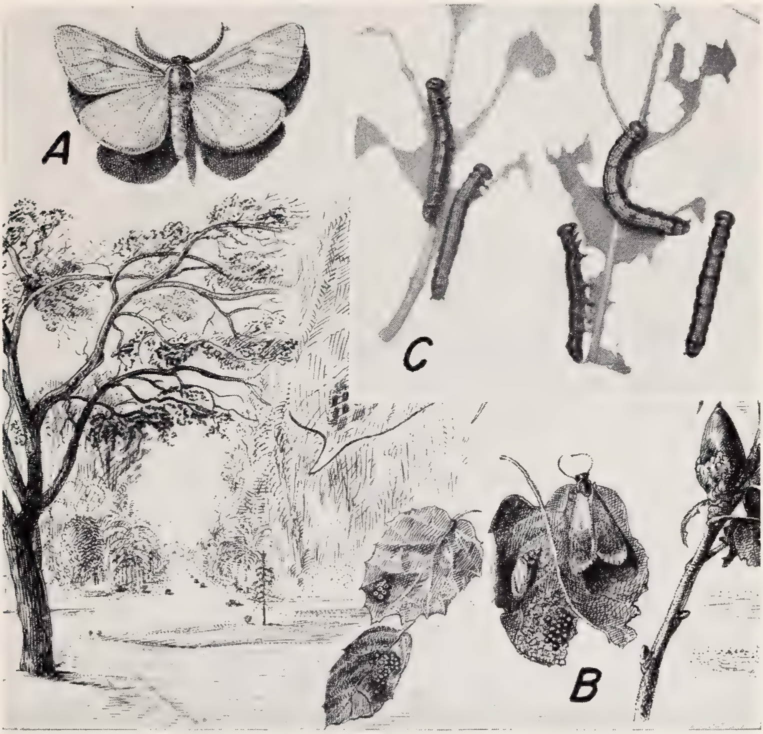

FIGURE 35.—The California oakworm (*Phryganidia californica*): *A*, Adult moth, natural size; *B*, moth laying eggs on under side of oak leaves; *C*, caterpillars, natural size.

OAK MOTHS

The California oakworm (*Phryganidia californica* Pack.) (Dioptidae) (*29*) (fig. 35) periodically defoliates the various species of oaks in California and sometimes attacks other trees in the vicinity of heavily infested oaks. It is particularly injurious to shade and ornamental oaks in the San Francisco Bay district, and not only renders the trees unsightly but may seriously weaken or even kill them.

The moths have a body about ½ inch long, and wings of light brown with darker veins and a spread of about 1¼ inches. The males are distinguished by yellowish patches near the center of the forehead and by their broader and more feathery antennae. Full-grown caterpillars are about 1 inch long, and dark olive green, with conspicuous black and yellow longitudinal stripes on the back and sides.

The females lay eggs in groups of 2 to 40 on the under side of oak leaves, on tree trunks, or other convenient places. The young caterpillars skeletonize the leaves, and later, as they reach full growth, consume all the leaf. Two generations are produced each year. The moths fly in June and again in November. The winter is passed in the egg and early larval stages.

Natural enemies include the spined soldier bug, a tachinid fly, and several species of wasplike parasites. A wilt disease takes a heavy toll of the caterpillars during epidemics. As a result of these natural control agencies, outbreaks occur only at irregular intervals.

This defoliator can be controlled by spraying in March and April with lead arsenate or DDT emulsion sprays when the worms are very small and again during the latter part of July and early in August.

TUSSOCK MOTHS

The tussock moths (Lymantriidae), a very destructive group of leaf-feeding insects, attack coniferous as well as broadleaved trees. The adults are dark-brown or dull-colored, very fuzzy moths, chiefly nocturnal in habit. The males fly, but the wings of the females are but short pads, of no use for flight. The abdomens of the females are large and covered with a mat of dark-gray hair. The full-grown caterpillars are strikingly marked and very hairy with prominent pencils or small tufts of hairs on all the body segments, the whole giving much the appearance of a toothbrush. The larval hairs are easily detached and in some species are somewhat poisonous, causing a rash or eczema when they come in contact with the skin.

The female lays small white eggs in a mass on top of her own cocoon and covers them with a frothy, gelatinous secretion in which are embedded hairs from her body. The eggs hatch into tiny, very hairy caterpillars. Since the females are unable to fly, the principal time of dispersion is probably during this young caterpillar stage, for the light, hairy caterpillars can be easily picked up and carried by air currents for long distances. When disturbed or when in search of food, the larger larvae lower themselves to the ground by silken threads and travel rapidly, but dispersion at this stage could be for only short distances. Pupation takes place within a gray cocoon made of silk mixed with larval hairs. The cocoons may be attached to the twigs, limbs, or trunks of trees or on the underbrush. They are sometimes formed in masses six or seven layers deep, and in such masses the moths from the lower layers are unable to emerge.

The Douglas-fir tussock moth (*Hemerocampa pseudotsugata* McD.) (*3*) (fig. 36) is a defoliator of major importance in the Douglas-fir and true-fir forests of eastern Oregon, Washington, British Columbia, Idaho, Colorado, and Nevada. It was first discovered in 1918 in British Columbia, where it was severely defoliating Douglas-fir, and later was noted at several points in Canada. It was first found in the United States in 1927, defoliating alpine fir at Jarbridge, Nev. From 1927 to 1930 a major outbreak

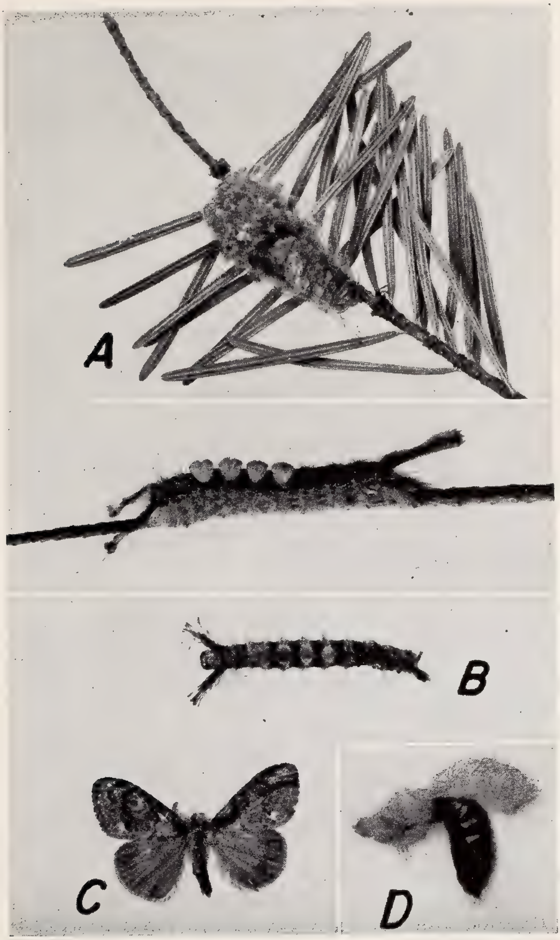

FIGURE 36.—The Douglas-fir tussock moth (*Hemerocampa pseudotsugata*): *A*, Female laying eggs on cocoon; *B*, larvae, *C*, male moth; *D*, chrysalis. Natural size.

of this moth occurred at widely separated points in Canada, northeastern Washington, northeastern Oregon, Idaho, and Nevada. The outbreak on the Colville National Forest, in Washington, which reached a peak in 1929 and subsided in 1930, spread over many square miles and killed at least 300,000,000 board feet of Douglas-fir and true-fir. Many of the Douglas-firs that were not killed outright by the defoliation later succumbed to the attacks of the Douglas-fir beetle. One minor outbreak has been noted—from 1937 to 1939—which killed considerable timber over limited areas of the Malheur and Umatilla National Forests in eastern Oregon. Then in 1946 and 1947 a tremendous outbreak developed over 500,000 acres in the fir forests of northern Idaho, northeast-

ern Oregon, and eastern Washington, which might have destroyed nearly 2 billion board feet of timber had it not been brought under control with aerial spraying on a vast scale. Such extensive outbreaks have often been followed by disastrous forest fires.

The Douglas-fir tussock moth shows a decided preference for Douglas-fir and species of true fir and can increase to epidemic numbers only when feeding on these preferred host trees. It will, however, feed on other species of conifers when they are mixed with firs, and even on the underbrush. Defoliation first occurs at the tops of trees, and as this foliage is destroyed the caterpillars work down on the lower foliage.

The caterpillars of this tussock moth are striking-looking creatures, with brightly colored tufts of hairs. When full grown they are from 3/4 to 1 inch long, with gray or light-brown bodies and black, shiny heads. Two long brushes, or pencils, of black hairs fully 1/4 inch long, suggest horns, directly behind the head, and a similar but longer tuft is at the posterior end of the body. On the upper side of the first four and the last abdominal segments are dense, light-brown, or cream-colored tufts of hairs about 1/16 inch long, and numerous red spots. Along the sides of the body are somewhat broken, narrow, orange stripes, while the lower side of the body is nearly naked, with the prolegs only sparsely covered with hairs.

The dull, brownish-gray moths are far more ordinary looking than their handsome larvae. The males are about 1/2 inch long and have a wing expanse of nearly 1 inch. The wingless females are about one-half as long as the males.

Normally there is one generation a year. The small, hairy caterpillars hatch from the eggs early in the spring and do a great deal of migrating before settling down to feed on the new foliage. At this stage they are easily carried long distances by the wind. Early in June evidence of their work becomes conspicuous just after the small larvae have killed the new foliage by girdling the base of expanding buds, and by the first of August defoliation may be so severe as to be noticeable over wide areas. The hairy larvae do considerable traveling during their search for food and drop from the trees by long silken strands, causing a conspicuous webbing of the forest. They reach full growth early in August and then pupate inside grayish-brown, spindle-shaped cocoons, which are covered with hairs and attached to various parts of the trees and neighboring shrubs. Moths appear the latter part of August and mate soon after emergence. The winter is passed in the egg stage. Eggs are laid by the wingless female moth in masses on top of the old cocoon from which she has emerged and are covered with a frothy white substance liberally mixed with hairs from her abdomen. These cocoons and egg masses are among the most conspicuous evidences of tussock moth prevalence.

One of the most important parasites of the Douglas-fir tussock moth is a tachinid fly, somewhat larger and more hairy than the ordinary housefly. The larvae of this fly live in the caterpillars and emerge after the caterpillars have formed their cocoons. A very small wasplike insect, *Trichogramma minutum* Riley, attacks

the eggs and destroys a high percentage of them. At least five other wasplike insects are important parasites of the larvae. A virus disease is highly effective in bringing epidemics under control.

The Douglas-fir tussock moth can be controlled with DDT sprays. In 1947 the outbreak in Idaho and eastern Oregon was brought under control by airplane spraying with 1 pound of DDT in 1 gallon of oil carrier per acre, applied to 413,469 acres—the largest aerial spraying project ever undertaken up to that time, and a highly successful one.

Other closely related species of tussock moths that feed on forest trees in the Western States are as follows:

Species of *Hemerocampa*	*Host and distribution*
oslari (Barnes)	White fir. California and Colorado.
vetusta (Bdv.)	Oak, poplar, willow, and various other broad-leaved trees. Pacific coast.
gulosa (Hy. Edw.)	Oak. California Sierras.
leucostigma (A. & S.)	Poplar and other broadleaved trees. In the east, and west into Colorado and British Columbia.

The rusty tussock moth (*Notolophus antiqua* (L.)) is a cosmopolitan species which is distributed over much of North America and Europe. It has been recorded in the West from California to British Columbia and east to Montana. The dark, hairy caterpillars have four dense, white, brushlike tufts of hair on their backs, two black pencils of hairs in front, and one on each side about midway of their bodies; they are $1\frac{1}{8}$ inches long when full grown. They feed on alder, ash, aspen, oak, poplar, willow, and other broadleaved trees and shrubs, as well as on various conifers.

The satin moth (*Stilpnotia salicis* (L.)) (*19*) is a very injurious leaf-eating enemy of poplars and willows. This moth, which is native to Europe, was first reported in 1920, both in New England and British Columbia. Since then the British Columbia introduction has spread throughout western Washington and into Oregon. It is a serious pest of planted shade and roadside trees, and may prove destructive to native poplars and willows.

The adults are large white moths with a satiny luster, a wing expanse of approximately $1\frac{3}{4}$ inches, black eyes and legs, and a tuft of hairs at the tip of the abdomen. The full-grown caterpillars are about 2 inches long, black with white markings on the sides, a row of nearly square white marks along the back, and have brown spines and long hairs.

There is but one generation a year. During the flight of the moths in July, eggs are laid on trees or other objects in oval patches covered with a white, satiny secretion which glistens in the sun. The young larvae feed for a short time and then spin small cocoons or hibernacula in bark crevices, where they pass the winter. They resume feeding in the spring, and the larvae reach maturity in June, and pupate in loosely woven cocoons attached to leaves or other objects.

It was introduced without its European parasites, but it is attacked by several native enemies, including tachinid flies, parasitic

wasps, sarcophagid beetles, mites, and birds. Some of these have proved very effective in holding it in check. From 1929 to 1934, five species of parasites of European origin were colonized and liberated in Washington. Four of these have become established and at least one, *Apanteles solitarius* Ratz., has become abundant enough to show apparent effect.

Direct control is obtained by spraying the trees in the spring with a stomach poison, such as lead arsenate. When egg masses are exceptionally abundant they should be treated with creosote.

TENT CATERPILLARS

Tent caterpillars (*Malacosoma* spp.) (*149*), which are responsible for the defoliation of many different species of trees and shrubs, can be recognized by the large compact webs at the terminals of branches, which are such a common sight during April and May. The various species are indigenous to this continent, being widely distributed over the United States. Outbreaks were recorded from Massachusetts as early as 1646. Coniferous trees are sometimes attacked, but the preferred hosts are deciduous trees and shrubs. While large forest areas are sometimes defoliated, the resultant damage is usually of no great importance, since deciduous trees can readily recover from the loss of foliage.

The caterpillars that construct the tents are usually yellow to brown, with rows of blue or orange spots and lines, and are lightly covered with long hairs. A heavy, silk-lined cocoon is usually formed in bark crevices or in leaves webbed together. The adults are tawny yellow or brown moths, or millers, and are frequently seen flying about lights at night.

Tent caterpillars usually have but one generation a year. Adult moths appear in midsummer and deposit masses of eggs in bands encircling small twigs. The eggs do not hatch until the leaves appear the following spring. The young larvae feed on the new foliage, construct the large tents on terminal branches, and reach maturity early in the summer. They then form pupae, and the adult moths appear soon after.

Aside from the several species of predaceous beetles and bugs that feed on the caterpillars, there are parasitic insects that lay their eggs within those of the moth, and their minute larvae develop within the host eggs and destroy them. Further control is accomplished by parasitic insects that breed within the caterpillars and the pupae. Birds also play an active part in controlling the tent caterpillars, many species feeding on the caterpillars, others feeding on the eggs, and still others on the moths. Often the most complete control is accomplished by a wilt disease that rapidly spreads among the colonies of caterpillars and leaves few survivors.

There are six common species of tent caterpillars in the West, and they are most easily distinguished in the field by the markings on the larvae.

The forest tent caterpillar (*Malacosoma disstria* Hbn.) is dusky brown with a row of diamond or keyhole-shaped white spots along the back and sides and with fine brown hairs. It feeds in large

colonies, without forming tents, on alder, birch, poplars, willows, and a large number of broadleaved trees. These caterpillars are distributed generally over the United States.

The eastern tent caterpillar (*Malacosoma americana* (F.)) has a white line on the back, bordered with reddish brown, and on the sides a row of blue spots and reddish-brown and yellow lines. It feeds on various fruit, shade, and forest trees in the Eastern States and is found in the Rocky Mountain region from New Mexico to British Columbia.

The California tent caterpillar (*Malacosoma californica* Pack.) is orange red to brown above and paler brown below, with a blue line on each side. This species is found in California, where it feeds on ash, madrone, oak, willow, and other forest, shade, and fruit trees.

The blue-sided tent caterpillar (*Malacosoma constricta* Stretch) has an orange-brown body, with distinctly blue sides and blue dots along each side of the center. It feeds on oak and other trees in Arizona, California, and Oregon.

The Great Basin tent caterpillar (*Malacosoma fragilis* Stretch) (fig. 37) is distributed in the Great Basin region between the

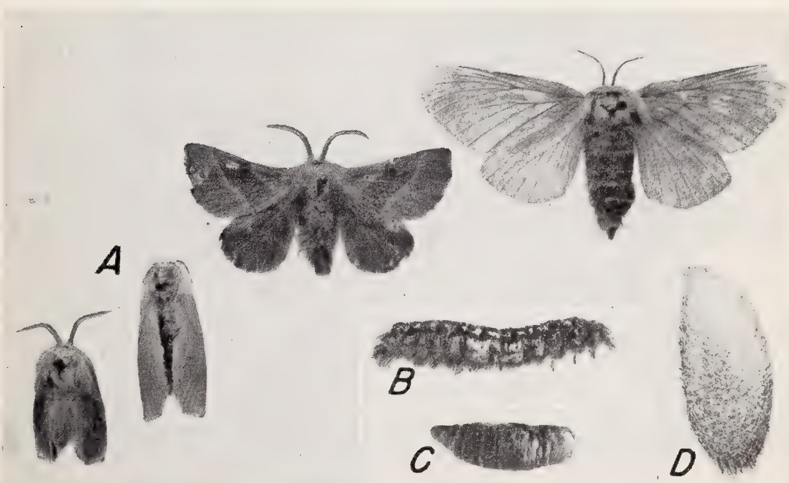

FIGURE 37.—The Great Basin tent caterpillar (*Malacosoma fragilis*): *A*, Adults; *B*, larva; *C*, pupa; *D*, cocoon. Natural size.

Rocky Mountains and the Cascade-Sierra Nevada ranges, where it feeds on bitterbrush, aspen, oak, poplar, willow, and other shrubs and trees. The caterpillars of this species are distinguished by having a pale-blue head and a brown-to-black body, with a broad, pale-blue stripe down the middle, fine orange lines on each side of the center, and two blue spots on the sides of each segment. The hairs are whitish.

The western tent caterpillar (*Malacosoma pluvialis* Dyar) (fig.

38) is the common coastal species in the Pacific Northwest. Its favorite food is the alder, though it also feeds on other forest and fruit trees. The caterpillar is brown, with a row of elliptical blue spots down the center and two orange spots on each segment. On the sides are pale orange lines and spots.

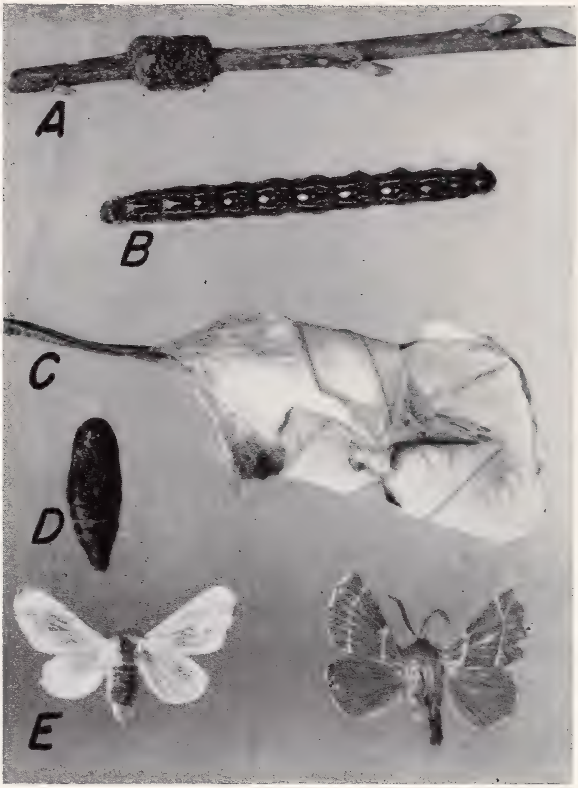

FIGURE 38.—The western tent caterpillar (*Malacosoma pluvialis*): *A*, Egg mass on alder branch; *B*, full-grown caterpillar; *C*, cocoon webbed in curled leaf; *D*, pupa; *E*, adult moths. All natural size.

LOOPERS, SPANWORMS, OR MEASURING WORMS

The leaf-feeding caterpillars of the (Geometridae) family of moths infest a great many species and varieties of trees and plants. Some species are among the most destructive defoliators of forest trees. The caterpillars are smooth, nearly hairless, with three pairs of true legs in front and two or three pair of prolegs on the rear of the abdomen. These species can easily be recognized by the characteristic way in which the caterpillars travel. They move along by grasping with the hind pairs of prolegs while they extend the body forward, then holding with the front legs while they hump their backs to bring up their rear. This produces a looping motion, from which arises the common names of loopers, span-

worms, inchworms, or measuring worms. Adults are medium-sized, slight-bodied, and light-colored moths of which the hemlock looper and the oak looper are typical examples.

The hemlock looper (*Lambdina fiscellaria fiscellaria* (Guen.)) (*157*) is a very destructive defoliator in the spruce, hemlock, and balsam fir forests of the Northeastern States, through Canada, the Lake States, and along the northwestern coast. At intervals it appears in great numbers, strips the needles from trees over large areas, and kills them. These defoliated trees become very dry, and soon form jungles of fallen trees and broken tops, which are frequently swept by disastrous fires.

A subspecies of *Lambdina fiscellaria* that destroys the spruce-hemlock forests along the coast of Oregon, Washington, and British Columbia is *lugubrosa* Hulst (fig. 39) (*77, 135*). During the last 60 years it has figured in four or five major outbreaks and several minor ones. In the earliest outbreak recorded, about 1889 to 1891, a vast amount of timber in Tillamook and Clatsop Coun-

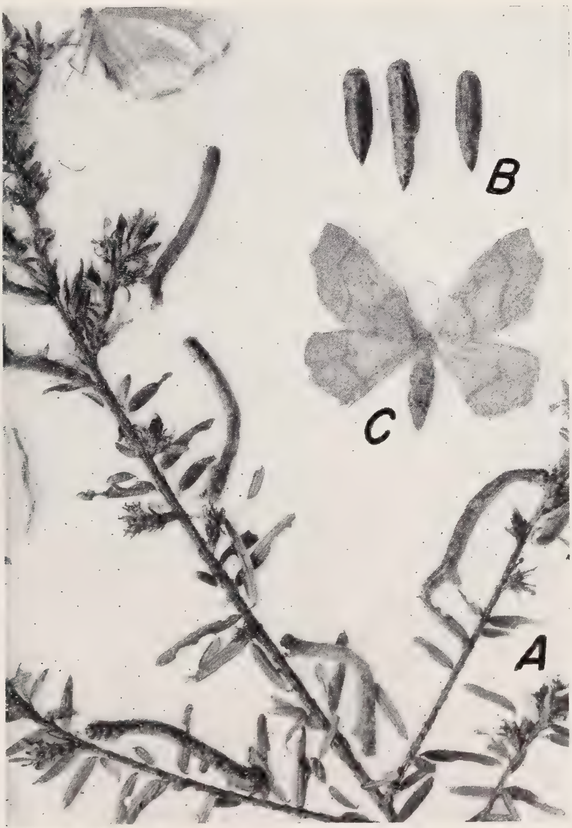

FIGURE 39.—The hemlock looper (*Lambdina fiscellaria lugubrosa*) : *A*, Larvae on branch; *B*, pupae; *C*, adult moth. Natural size.

ties, Oreg., and Grays Harbor County, Wash., was destroyed. From 1911 to 1914 the hemlock looper killed much hemlock in Stanley Park, Vancouver, B. C. Another major outbreak occurred again in Tillamook County in 1918–21, when several townships were affected and 500 million board feet of hemlock and Douglas fir were reported to have been killed. A severe outbreak occurred in Pacific and Grays Harbor Counties, Wash., from 1929 to 1932, when 50,000 acres were involved and about 200 million board feet of hemlock timber was destroyed. Losses in Pacific County were reduced in 1931 through the first airplane dusting experiment attempted against a forest defoliator in the western part of the United States. Again, between 1943 and 1945 there was another outbreak in Clatsop County, Oreg., covering some 12,000 acres,

FIGURE 40.—Western hemlock defoliated and killed by the hemlock looper in Clatsop County, Oregon, in 1945.

with a loss of timber estimated at 40 million board feet (fig. 40). Airplane spraying with lead arsenate and DDT was used to control this outbreak.

Although western hemlock is the preferred host, the caterpillars appear in countless thousands when an outbreak occurs and feed on any foliage at hand. Douglas-fir, Sitka spruce, and western redcedar may be heavily attacked when in mixture with hemlock; also huckleberry, salal, and broadleaved forest shrubs and trees are frequently eaten. In fact, when the caterpillars are exceptionally numerous, nothing green is left on the infested areas.

The moths of the hemlock looper are light buff, with a wing expanse of about 1½ inches. The forewings are marked with two wavy lines and the hind wings with one wavy line. They fly, mate, and lay eggs late in September and during October. The eggs are about the size of a pinhead, blue to gray-green or brown with a characteristic impression, and are attached to the moss on the tree trunks, or to twigs or branches. The winter is passed in the egg stage, and the eggs hatch the following spring. The young larvae, which are about ¼ inch long, crawl up the tree trunks and start feeding on the young needles. The first feeding takes place in May, June, and the early part of July and is not particularly noticeable. However, from the middle of July to October the feeding of the caterpillars causes a heavily infested forest to turn yellowish red and then brown, as though scorched by fire. Late in summer the caterpillars feed on the foliage, clip off small twigs, crawl over the trunks, cling to shrubs, and drop by silken webs from the trees to the ground. These silken webs may become so abundant that the whole forest looks and feels like one big cobweb. When full grown, the caterpillars are about 1½ inches long, green to brown, with diamond-shaped markings on the back. They drop to the ground in August and September and secrete themselves in protected places, such as crevices of the bark or under debris on the ground, and there transform to pupae.

The mottled, greenish-brown pupae, about ½ inch long, are unprotected by a cocoon. The moths appear within 10 to 14 days and during an epidemic are so abundant as to give the impression of a snowstorm in the woods. Creeks, springs, and rivers are covered with the dead bodies, and tree trunks are plastered with them until heavy rains wash them into the ground or carry them away. There is one generation annually.

Outbreaks of the hemlock looper usually last about 3 years, after which they are generally brought under control by the action of parasites, predators, and disease. A polyhedral virus disease is particularly effective in decimating the caterpillars. Heavy rains during the flight period reduce egg laying, checking an epidemic and hastening its decline.

Although nature will ultimately bring outbreaks under control, a vast amount of timber may be saved if artificial control measures are applied to protect the trees from heavy defoliation. It has been found that trees can recover from a 50-percent defoliation, and in some cases a 75-percent defoliation is not fatal unless the trees are subsequently attacked by bark beetles. At present, air-

plane spraying (*90*) offers the only practical means of controlling this defoliator on large forest areas at a reasonable cost. Application of 1 pound of DDT in a gallon of fuel oil per acre is very effective in destroying young caterpillars as they travel to the tops of the trees to feed. It should be applied after the eggs have hatched, preferably from the middle of June to mid-July.

FIGURE 41.—The oak looper (*Lambdina fiscellaria somniaria*): *A*, Caterpillars on defoliated branch; *B*, pupae; *C*, adult moths, female above, male below. Slightly enlarged.

The oak looper (*Lambdina fiscellaria somniaria* Hulst) (fig. 41) represents a race of loopers so closely related to the hemlock looper as to be scarcely distinguishable. This race shows a distinct preference for Oregon white oak, on which it feeds in Oregon and northward into British Columbia. Other trees may be attacked, but usually only when intermingled with the preferred host tree. In some seasons the oaks over large areas in Willamette Valley, Oreg., are completely defoliated by this species. No permanent damage is done, however, since the oaks are able to leaf out again the following year.

The Monterey pine looper (*Nepytia umbrosaria* (Pack.)) in the larval stage is a light-green, smooth caterpillar, which ties the needles of young Monterey pines together at the tips of branches and feeds on them in central California. The adult moth is mottled gray with a wingspread of about 1½ inches. **The phantom hemlock looper** (*Nepytia phantasmaria* (Stkr.)) feeds on western hemlock in Washington and British Columbia, often occurring in large numbers in outbreaks of the hemlock looper or blackheaded budworm. The moths are white with numerous black markings on the wings. **The false hemlock looper** (*Nepytia canosaria* (Wlkr.)) feeds on hemlock, Douglas-fir, larch, and spruce in the Northwest and Canada.

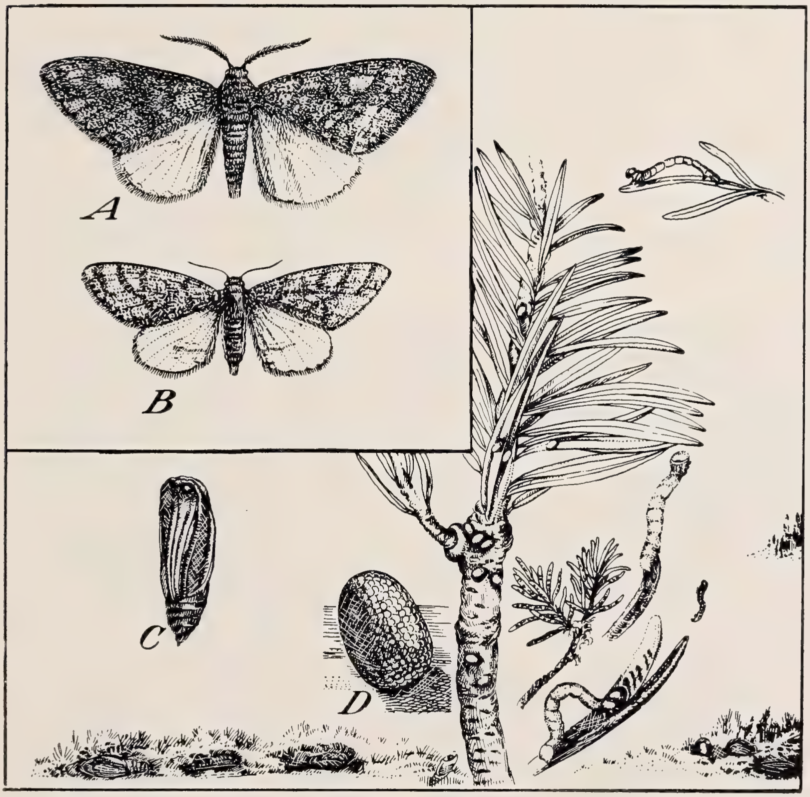

FIGURE 42.—The New Mexico fir looper (*Galenara consimilis*) : *A*, Male moth; *B*, female moth; *C*, pupa (A-C slightly enlarged) ; *D*, egg, greatly enlarged. (Drawings by Edmonston.)

The New Mexico fir looper (*Galenara consimilis* Hein.) (fig. 42) has periodically destroyed timber over considerable areas in the spruce-fir type at the higher elevations in the southern Rocky Mountain region, particularly in New Mexico. Douglas-fir seems

to be the preferred host, but true fir and spruce foliage is also eaten.

BUDMOTHS, BUDWORMS, AND LEAF ROLLERS

One group of moths, belonging largely to the family Tortricidae, lay their eggs on the needles of coniferous trees or the leaves of various broadleaved trees, and the young caterpillars feed on the opening buds and new leaves or needles, drawing these together with a silken web. Later, as they become larger, they may leave their protective web and feed openly on the leaves or older needles and if numerous will completely defoliate the tree. When growth is completed the larvae transform to the pupal stage, usually in small webs spun about the dead foliage at the tips of the branches, and from these the adult moths emerge.

Under normal conditions the damage consists only of a few dead tips or partly eaten leaves. When buds are killed, subsequent branching results at these points, but seldom is the life of the tree threatened. When epidemic outbreaks occur, large forest areas may be completely defoliated and killed.

The spruce budworm (*Choristoneura fumiferana* (Clem.)) (*62, 64, 125, 153*) (fig. 43), is one of the most destructive defoliators in this group. It is widely distributed through the fir forests of Canada, the Northeast, the Lake States, the Rocky Mountain re-

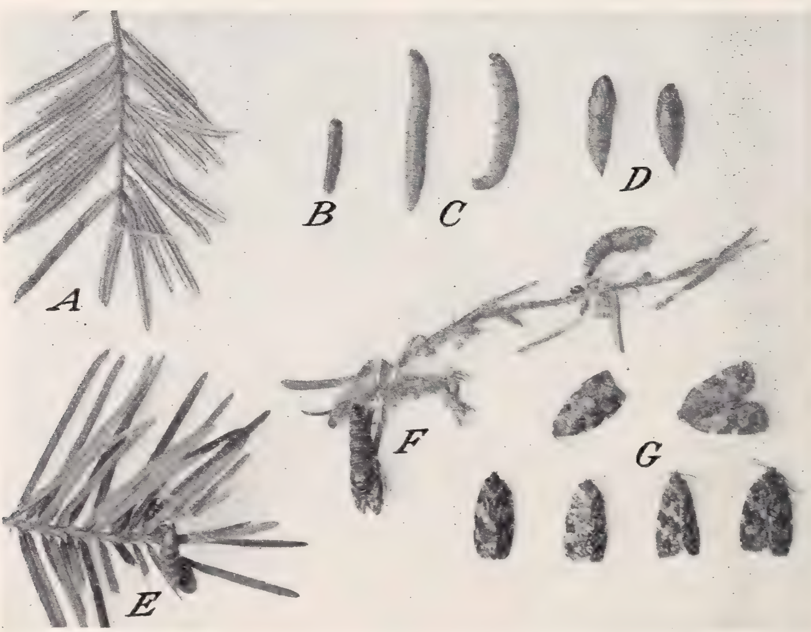

FIGURE 43.—The spruce budworm (*Choristoneura fumiferana*): *A*, Eggs on under side of fir needle; *B*, half-grown caterpillar; *C*, full-grown caterpillars; *D*, pupae; *E*, fir twig with pupa attached; *F*, defoliated fir twig with empty pupal cases; *G*, adult moths. All natural size. (Evenden.)

gion, the Southwest, and the Pacific Northwest from Alaska to California. There are many records of spruce budworm epidemics, in which enormous numbers of spruce and balsams have been destroyed, in the Northeast, in Canada, and in the Lake States. Although it had been found in the West as early as 1915, it was not until 1922, when two outbreaks were recorded in widely separated sections of Idaho, that it was recognized as an important enemy in western forests. Since then outbreaks of tremendous scope and destructiveness have occurred in the northern Rocky Mountain region, in Colorado, and in the Pacific Northwest. Though it is not known whether the spruce budworm migrated or spread to the western part of the United States from infested areas in the East, it is believed to be indigenous to the West, and during the last 30 or 40 years it has been at such a low endemic stage as to escape attention.

The adult spruce budworms are small, mottled, buff-colored to grayish moths with a wing expanse of approximately ⅞ inch, and with no distinctive markings, the general color tone being a dull gray. The oval, scalelike eggs, which are light green and about $\frac{1}{16}$ inch in diameter, are laid on the under side of needles, overlapping like shingles, with about one-third of the egg exposed. The mature larvae are approximately 1 inch long, deep brown, with yellowish, pale-green markings and numerous small, wartlike growths along the sides.

The moths can be seen hovering around infested trees late in July or early in August. The females lay their eggs on the needles of the upper branches of fir and spruce trees, where the tops are in the sunlight. A female lays approximately 150 eggs in masses of 12 or more, and these hatch in about 10 days. After hatching, the young larvae wander about for a few days in search of a suitable place to spin their cocoons, in which they hibernate until the following spring. In May they emerge from their winter hibernacula and first mine old needles, then attack the opening buds, entering them either directly through the base or between the opening scales, and hollow them out. As the new tender needle growth develops, this is fed upon. Later the larvae bind the needles at the tips of the branches together loosely with silk, bite them off at the base, and form a shelter of dead needles, bud scales, and frass. When disturbed, the larvae hide in these retreats, or wriggle violently, drop, and hang on silken threads, using these threads for their return to the nests if no further disturbance occurs. After 3 or 4 weeks of feeding, about the last of July, the larvae reach maturity and construct loose cocoons of silk and dead needles, in which they pupate. The moths emerge within 10 to 12 days. There is one generation annually.

When attacks are heavy, entire trees are stripped of foliage and killed and large forest areas take on a brownish, scorched appearance (fig. 44). When defoliation is not so complete the trees show a blighted or scorched appearance at the tips of limbs where the new foliage has been destroyed. Even moderate feeding tends to reduce growth, weaken the trees, and render them susceptible to later destruction by secondary insect enemies.

FIGURE 44.—A forest defoliated by the spruce budworm.

In the western part of the United States the true firs and Douglas-fir appear to be preferred hosts of the spruce budworm, and the greatest damage has occurred in pure stands of these two species. The budworm, or closely related varieties, has also been found attacking Engelmann spruce, western larch, western hemlock, and western white, ponderosa, and lodgepole pines. Budworm attacks on pines are usually limited to individual trees growing in association with the preferred hosts, though serious outbreaks in pure lodgepole pine have occurred in and adjacent to the southwestern corner of Yellowstone National Park. The new foliage is destroyed first, old needles being attacked only when the preferred supply is exhausted. Larvae will often migrate from one tree to another in search of new foliage rather than feed on old needles.

Like most defoliators, the spruce budworm is preyed upon by numerous insect parasites and predators, and these in normal years tend to keep the pest under control. Natural enemies and a shortage of food will eventually subdue most outbreaks.

Control of spruce budworm outbreaks by airplane spraying has been demonstrated as feasible by a pilot experiment in 1948 and large scale operations conducted in Oregon and Washington during 1949, 1950, and 1951 by private timberland owners, State agencies, and the Federal Government. One pound of DDT in 1 gallon of fuel oil was applied per acre during a short period in

May and June, when expanding fir buds exposed the small budworm larvae to insect enemies and sprays. In 1949, 267,000 acres were treated at a cost of $1.20 per acre, and in 1950, about 933,700 acres at $1.06 per acre. These spray operations reduced the infestations by 97 to 99 percent.

The sugar pine tortrix (*Choristoneura fumiferana* var. *lambertianae* (Busck)) (fig. 45) is at times very destructive to the new

FIGURE 45.—The sugar pine tortrix (*Choristoneura fumiferana lambertianae*) and its damage to sugar pine terminals.

buds and pollen bodies of sugar pine, killing as much as 90 percent of the new growth on the trees. The caterpillars feed in colonies within a web on the terminal shoots and transform to adults in July. The adults are speckled tan-to-golden moths with a wing expanse of about ⅞ inch.

The black-headed budworm (*Acleris variana* (Fern.)) (*4, 135*) is an important defoliator of hemlock, true fir, and spruce forests in the northern part of the United States, Canada, and Alaska. In the Northeast and in eastern Canada it has appeared in destructive numbers only where mature true fir forms a high percentage of the stand.

In the Pacific Northwest western hemlock and Pacific silver fir appear to be the preferred hosts, although grand fir, alpine fir, Douglas-fir, and Sitka spruce are also attacked during outbreaks. In this area on the Olympic Peninsula of Washington, two or more outbreaks have been recorded in which thousands of acres of western hemlock have been severely defoliated. Fortunately, these outbreaks have resulted in the killing of very little merchantable timber. In contrast, an outbreak in 1940–44 in the northern part of Vancouver Island, British Columbia, killed a vast amount of hemlock.

The small moths, gray or dappled with brown, black, orange, and white, have a wing expanse of $\frac{3}{4}$ inch. They appear during August and September, mate, and lay their eggs on the under side of the needles. The eggs remain unhatched during the winter, but in the spring the small, pale caterpillars appear and start feeding on the new foliage of opening buds. They work in much the same way as the spruce budworm, boring into and feeding on the opening buds and webbing the new needles together to form a protective case within which they feed. As they develop they become bright green, and the head turns black. If disturbed they actively wiggle backwards and drop to the ground by silken threads. They reach full growth by the last of July, at which time they are a trifle more than $\frac{1}{2}$ inch long and may have brown heads.

Usually they confine their work to the new growth, but if they are numerous the larger caterpillars will leave the nests and feed on the older needles, bringing about complete defoliation. Pupation takes place within a web made among the dead needles and frass on the twigs. Prior to emergence, the pupa, which is dark reddish brown with a greenish tint, works partly out of the web so as to allow the moth freedom to emerge. There is but one generation a year.

The black-headed budworm does a little feeding every year, but its work is scarcely noticeable. When an attack is heavy toward the end of July, the forest takes on a reddish-brown appearance. This is due to the dying of the new foliage that is partly eaten but remains attached to the twigs by the webs of the caterpillars. The small, wriggly, green caterpillars or the brown pupae can be found among the webs at the tips of the branches. For some reason outbreaks of this insect on the Olympic Peninsula, which have caused heavy defoliation of hemlock stands over vast areas—even repeated defoliations for two or more years—have killed little or no timber, whereas similar outbreaks on Vancouver Island, a little farther north, have been disastrous. Comparable defoliation by the hemlock looper apparently is much more damaging than that by the black-headed budworm.

The larvae of the black-headed budworm are parasitized by numerous insects and are affected by a polyhedral virus disease. These agents become dominant and bring outbreaks under control within 2 to 3 years.

The pine tube moth or **lodgepole pine needle tier,** (*Argyrotaenia pinatubana* Kearf.) (*26*) (fig. 46) is found in the Rocky Mountain region, where it works on lodgepole and whitebark pines. Usually

FIGURE 46.—The pine tube moth (*Argyrotaenia pinatubana*): *A*, Webbed foliage; *B*, a silk-lined needle tube; *C*, full-grown larvae. Enlarged.

it is not particularly destructive, but from 1921 to 1925, working in conjunction with the lodgepole sawfly (*Neodiprion burkei* Midd.) (p. 118), it destroyed trees over a large area of immature lodgepole pine near West Yellowstone, in Montana. Since the cessation of the sawfly epidemic the pine tube moth is still present in many areas, but has ceased to be destructive.

The adult is a small brownish-gray moth with darker patches and bands on the forewings and a wing expanse of about ½ inch. Eggs are laid during the latter part of June and early in July in groups of 2 to 30, with an average of about 10 per cluster, on the concave side of lodgepole pine needles. These eggs hatch in 7 to 10 days, and the young larvae crawl over the foliage until needles satisfactory for their attack are found—usually those of the current year's growth. Each larva then enters a needle by biting a circular hole near the tip and spends from 2 to 3 weeks in feeding on the interior tissues. The inside of the mined needle is lined with a papery, white, closely woven web to form a tube. At an early period in the growth of the larva or when it becomes too large for the mined needle, several other needles are drawn to it and bound together so as to form a new and larger tube (fig. 41, *B*). This tube is also lined with a papery white web and has an opening at each end, that allows the insect to leave quickly when disturbed. Often a caterpillar will abandon one tube and form a new one. Feeding takes place within the tube, and as the caterpillar becomes larger the tube is extended farther down the needles, often to the base. During the latter part of August the mature caterpillar, which is dark green and about ½ inch long, drops to the ground on a silken thread and, after crawling into the mat of old needles, spins a loosely woven cocoon in which it passes the winter in the pupal stage. The adult emerges the following May or June, completing one single annual generation. The work of the pine tube moth is recognized by the silk-lined tubes, which may consist of as many as 16 needles webbed together, and which, as a result of the feeding, turn brown and die.

The orange tortrix (*Argyrotaenia citrana* Fern.) in the larval stage feeds at the base of needles on terminal and lateral buds of Monterey pine in California. The adults are small tan-to-brown moths.

The spruce bud moth (*Zeiraphera ratzeburgiana* Sax.) is an introduced pest that has become established in the Pacific Northwest and Alaska. The small, light-brown moths, with darker diagonal markings, and a wing expanse of about ½ inch, lay their eggs on spruce needles. Each young caterpillar crawls into an opening bud and feeds on the tender new needles, webbing them together to form a shelter, within which it feeds. Growth is completed late in the summer, when the larvae reach a length of ⅜ inch, and the chrysalis is formed in the shelter at the tip of the infested twig. The adults emerge late in the summer. There appears to be one generation a year. The damage has been frequently noted on young Sitka spruce trees along the coast of Oregon and Washington. On many trees all the new tips are killed and the tree is made to

branch excessively. This bud moth is also reported from Engelmann spruce.

The larch bud moth (*Zeiraphera griseana* (Hübner)), another European species, has recently caused heavy defoliation of larch and white fir over 86,000 acres in eastern Washington. The larvae feed on the tender new growth, causing damage similar to that of the preceding species. It has also been reported from foliage of Engelmann spruce and Douglas-fir and ranges through Oregon, Washington, British Columbia, Idaho, and Montana. The moths have grayish-white wings splotched with dark brown and black patches and a wing expanse of ½ to ¾ inch.

There are a large number of other budmoths and leaf rollers that infest the buds and young, tender leaves of various broad-leaved trees and shrubs. This damage is often serious in orchards but seldom is important in the forest, therefore no attempt is made to discuss them.

NEEDLE MINERS

Some leaf-eating insects have the habit of feeding internally on coniferous needles and thus protecting themselves within a thin, leafy covering. These are called needle miners. A great many of them cause only an insignificant amount of damage, but a few, such as the lodgepole needle miner, may defoliate extensive areas and contribute to the destruction of the timber cover on entire watersheds, as has happened in parts of the Yosemite National Park in California.

Outbreaks of needle miners are eventually brought under control by native parasites and climatic conditions, so control measures are seldom needed. Direct control through the use of sprays or dusts is difficult to obtain, since the insects are not easily reached. Experiments by Yuill (*163*) indicated that light, penetrating oil sprays to which nicotine had been added offered promise of being effective for the protection of valuable trees. More recent experiments have shown that benzene hexachloride is even more effective than nicotine. A spray containing 0.1 pound of the essentially pure gamma isomer, 0.06 gallon of auxiliary solvent, and 0.94 gallon of fuel oil can be applied at the rate of 1 gallon per acre.

The lodgepole needle miner (*Recurvaria milleri* Busck.) (*129*) (fig. 47) is the best representative of this group in the West. As its name implies, it mines the needles of lodgepole pine and has defoliated extensive areas of lodgepole pine in California, Idaho, Montana, and Alberta, Canada. It has also been found mining needles of western white pine and Jeffrey pine in epidemic areas. Outbreaks in Yosemite National Park, where it was first discovered, have so weakened the trees that they readily succumbed to attacks of the mountain pine beetle. Farther north its outbreaks have caused much less timber mortality. The adults are very small white or grayish moths only about ½ inch long. The caterpillars are very small greenish worms with black heads. This species has a 2-year life cycle, the moths flying in alternate years—even-numbered years in Canada and odd-numbered years in California. The

FIGURE 47.—The lodgepole needle miner (*Recurvaria milleri*), × 2.25.

peak of flight is in July, when eggs are deposited at the base of needles, usually beneath the needle sheath. Eggs hatch within 2 to 6 weeks, depending on temperature, and one-third of the needle is mined before winter. In the following spring the mining is completed, and the larvae transfer to another needle of the same year's growth. They are fully grown by June, when pupation occurs within the mined needle, and emergence follows in about 4 weeks.

Another species, *Recurvaria moreonella* Hein., mines ponderosa pine needles in Colorado, Utah, Arizona, and Oregon. Periodically it causes heavy loss of foliage around the Klamath Indian Agency in Oregon. From 1925 to 1928, and again from 1945 to 1947, a species identified as this one defoliated an area of several hundred square miles of lodgepole pine in the upper Deschutes Basin around Lapine, Ore. In size, markings, and habits this species closely resembles *R. milleri,* except that during an epidemic it has an annual generation with moths flying and laying eggs every year

between July 15 and August 15, instead of only in alternate years.

Other species of *Recurvaria* include *pinella* Busck, which mines ponderosa pine needles in Colorado, and *piceaella* (Kearf.), which mines the needles of various spruces in Colorado and in the Northeast.

FIGURE 48.—The spruce needle miner (*Taniva albolineana*): *A*, Damage on spruce twig; *B*, larvae; *C*, pupae; *D*, adults. Slightly reduced.

The spruce needle miner (*Taniva albolineana* (Kearf.)) (fig. 48) at times does considerable damage to spruce by boring into and mining needles, and webbing them together to form a mat of dead needles and frass held to the twigs by the webs. It is widely distributed through the Eastern States and Canada. In the West it has been found in Colorado, Idaho, Oregon, Washington, and British Columbia attacking Engelmann, blue, and Sitka spruces.

Adult moths are dark brown with a wing expanse of about 1/2 inch. The eggs are pale green and are laid in a group of about 7, shingle-fashion on the wider portion of a needle late in May. The larvae cut a hole near the base of a needle and mine the interior. Sometimes 3 to 8 larvae mine a single needle. When needles are consumed, they are cut off and held to the twig by a funnel-shaped web. Frass collects in the web and from 4 to 20 larvae may be found feeding together in one web mass. Feeding is complete by October, when the light greenish-brown larvae have reached a length of about 1/5 inch. They hibernate as larvae in a hollowed-out needle attached to the stem. When warm weather starts in March they resume feeding, pupate in April in silken cocoons in the web, and the moths emerge in May.

The Monterey pine needle miner (*Argyresthia pilatella* Braun.) is a small greenish caterpillar 1/6 inch long, which mines the needles of Monterey pine in central California.

The white fir needle miner (*Epinotia meritana* Hein.) caused considerable damage to white firs at Bryce Canyon National Park, Utah, from 1946 to 1948. The small, grayish, mottled black moths fly in July and lay eggs. The larvae develop very slowly during the fall and overwinter as tiny greenish larvae in fir needles. They complete their development the following spring and construct loose webs around several needles while mining them out. Aerial application of 2 pounds of DDT in 2 gallons of oil per acre in July and early in September gave partial control. The infestation declined in 1949.

The jack pine needle miner (*Zelleria haimbachi* Busck) (*42*) is a small, needle-sheath-mining lepidopteron, which severs the needles near the base, causes considerable webbing of needle clusters, and kills needles before they are half grown. The adults are small gray moths, which emerge about the end of July. This needle miner has been found damaging jack pine in Canada, lodgepole pine in Washington, and ponderosa pine in California.

The spruce budworm, the pine tube moth, and other closely related species frequently mine needles, especially during the first larval instars.

CEDAR TWIG AND LEAF MINERS

A group of small moths, belonging to the genera *Argyresthia, Recurvaria,* and *Epinotia,* while in the caterpillar stage, mine the twiglets and leaves of various cedar and cypresslike trees, causing the foliage to turn brown. The damage is not serious, except to the appearance of shade and ornamental trees. Most of the feeding is done early in the spring. A nicotine or DDT spray applied early in the spring is recommended for the prevention of damage to ornamentals.

The cypress tip moth (*Argyresthia cupressella* Wlsm.) mines the twiglets of Monterey cypress and other cupressine trees from central California north into Oregon and Washington. When the caterpillars reach full growth, they emerge from the twigs and spin white, feathery cocoons on the surface of the leaflets; and in

about 2 weeks the small tan moths emerge, fly, and lay their eggs in the crevices between the leaf scales. Two related species, *A. trifasciae* Braun (fig. 49) and *A. franciscella* Busck, are often

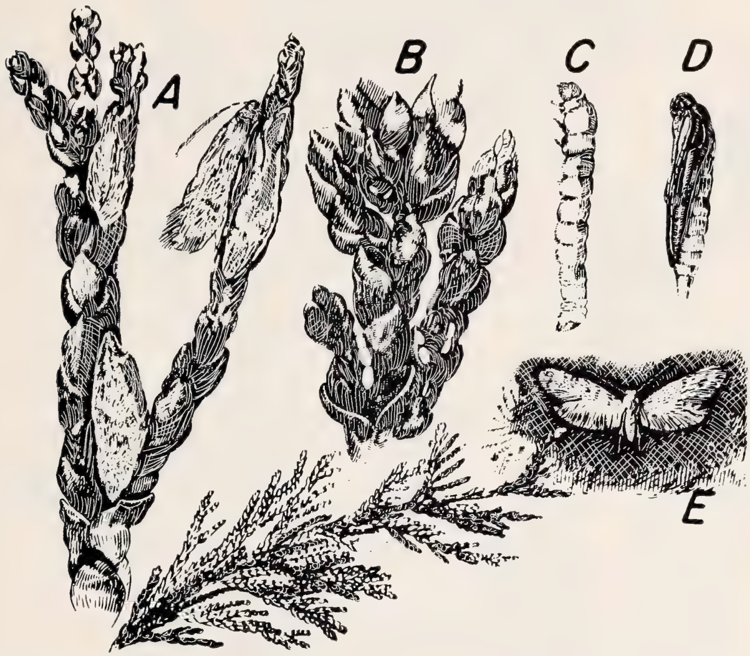

FIGURE 49.—The cypress moth (*Argyresthia trifasciae*): *A*, Adult and cocoons on twig; *B*, eggs in scale crevices; *C*, larva; *D*, pupa; *E*, adult. All greatly enlarged.

associated with the cypress tip moth and cause similar damage. The incense cedar tip moths (*Argyresthia libocedrella* Busck and *A. arceuthobiella* Busck) and attack the twigs and leaflets of incense cedar in Oregon.

The cypress webber (*Epinotia subviridis* Hein.) (fig. 50) in the caterpillar stage burrows through cypress leaflets, leaving a webby trail, and then ties bits of gnawed twigs and leaves together to form a small nest. Its work causes the foliage of cypress to turn brown early in the spring. It is distributed from southern California north into Oregon and Washington and is often found working with the cypress tip moth.

The cypress leaf miner (*Recurvaria stanfordia* Keif.) in the caterpillar stage mines the twiglets of Monterey cypress at Palo Alto, Calif., and *R. juniperella* Kearf. mines the twiglets and foliage of Sierra juniper.

LEAF MINERS

The leaves of many broadleaved trees are attacked by the larvae of many leaf-eating insects, which bore within and feed internally

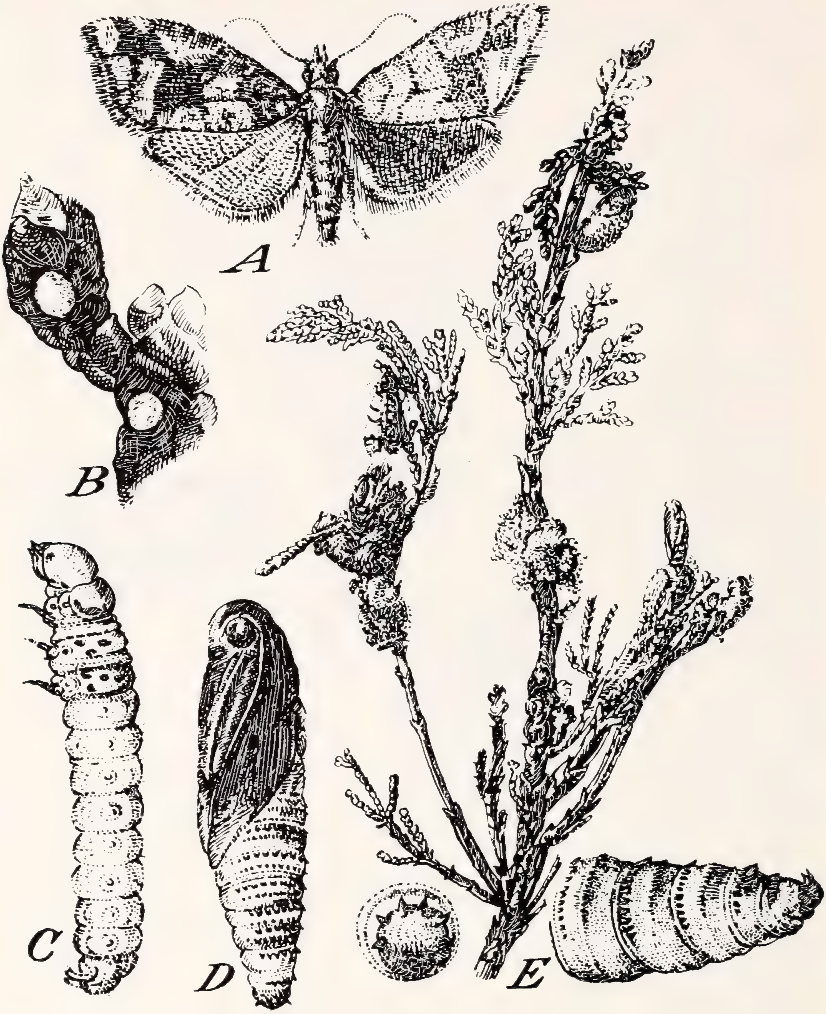

FIGURE 50.—The cypress webber (*Epinotia subviridis*): *A*, Adult moth, × 2.3; *B*, eggs, greatly enlarged; *C*, larvae, × 6.8; *D*, pupa, × 6.8; *E*, cocoons on twig (slightly reduced) and abdominal tip of pupa. (Drawings by Edmonston.)

on the leaf tissue. The damage they do is usually insignificant, since these trees are able to replace their foliage each year. Insects with the leaf-mining habit belong in the main to the order of the moths and butterflies (Lepidoptera), but a few beetles (Coleoptera), flies (Diptera), and wasps (Hymenoptera) also have this habit.

The leaf blotch miners hollow out irregular-shaped mines or blotches between the upper and lower surfaces of leaves. There

are many species that work on the leaves of various western broadleaved trees.

The madrone shield bearer (*Coptodisca arbutiella* Busck) mines the leaves of madrone and cuts out elliptical holes when constructing the pupal cases. Commonly associated with it in leaves of madrone is another leaf-mining species, *Marmara arbutiella* Busck.

The poplar leaf blotch miner (*Phyllonorycter tremuloidiella* Braun) attacks the leaves of aspen and poplars and constructs irregularly shaped mines between the upper and lower leaf surfaces. During heavy infestations nearly all the leaves on the lower parts of the trees are attacked, but infestation seldom extends above 50 feet. The damage results in premature shedding of the foliage. It has been reported from California, Idaho, British Columbia, and southern Utah and probably has a more extended range. When mature, the larvae change to small black pupae within the mines and then emerge as small drab-colored moths. Other species of *Phyllonorycter* include *P. salicifoliella* Chamb., which works in the under side of the leaves of willow, poplar, and cottonwood; *P. apicinigrella* Braun, which works in the under side of willow leaves; *P. felinella* Hein. (*27*), which works in the under side of sycamore leaves in California; *P. incanella* Wlsm., which works in both sides of alder leaves; and *P. arbutusella* Braun, which works in the leaves of madrone.

FIGURE 51.—Work of an aspen leaf miner (*Phyllocnistis populiella*).

Cameraria agrifoliella Braun works in the upper surface of leaves of coast live oak. *C. alnicolella* Wlsm. works in the upper surface of alder leaves. *C. umbellulariae* Wlsm. makes blister blotches on leaves of California laurel.

The aspen leaf miner *Phyllocnistis populiella* Chamb. (fig. 51) leaves a labyrinthian trail of frass as characteristic of its work in the under side of aspen and poplar leaves.

Common leaf miners in live oak include *Bucculatrix albertiella* Busck and *Abebaea subsylvella* Wlsm.

SAWFLIES

Sawflies form another important group of leaf-eating insects that in many cases cause extensive defoliation and destruction of timber. In the Northern States and in Canada, such species as the larch sawfly, the European spruce sawfly, and the jack pine sawfly have been responsible for the death of as much as 85 percent of the stand over thousands of acres. In the West the native sawflies occasionally develop widespread outbreaks and may cause heavy defoliation over limited areas, but the total timber destruction so far has not been great.

Sawflies (fig. 52) belong to the order of wasps (Hymenoptera) but in appearance are usually more like flies than wasps. They have thick, cylindrical bodies with four membranous wings, the hind pair somewhat smaller than the forewings. The head, thorax, and base of the abdomen are nearly equal in width. They range in size and color from small grayish insects not over ¼ inch long to large, showy species (*Cimbex*) over 1 inch long. They are called sawflies because of a sawlike attachment which the female carries at the tip of the abdomen and uses to slit open leaves or stems for the reception of her eggs. Usually only one egg is deposited in each slit, but as many as 14 or more punctures may be made in a single pine needle.

The larvae resemble hairless caterpillars except that most of them have from six to eight pairs of legs on the abdominal segments, in addition to the usual three pairs of true legs on the thoracic segments. Because of their resemblance to caterpillars the larvae are sometimes called false caterpillars; and since many are wormlike and often slimy, they are called slugs or worms. Most of them are typical external leaf chewers, but a few are leaf miners and even gall makers.

A characteristic feature of many sawflies is the cylindrical, papery, capsulelike cocoons which the larvae frequently construct for pupation. Some sawflies spin their cocoons in the soil; others on the debris of the forest floor; but still others may attach them to the needles or branches of the tree.

Sawflies, for the most part, complete their life cycle with one generation a year, although in some the diapause may last for several years. Many species pass the winter in the prepupal stage within the cocoons, and transform to adults in the spring. In some species part of the brood does not emerge from the cocoons until the second spring. The adults mate, and deposit eggs in the new

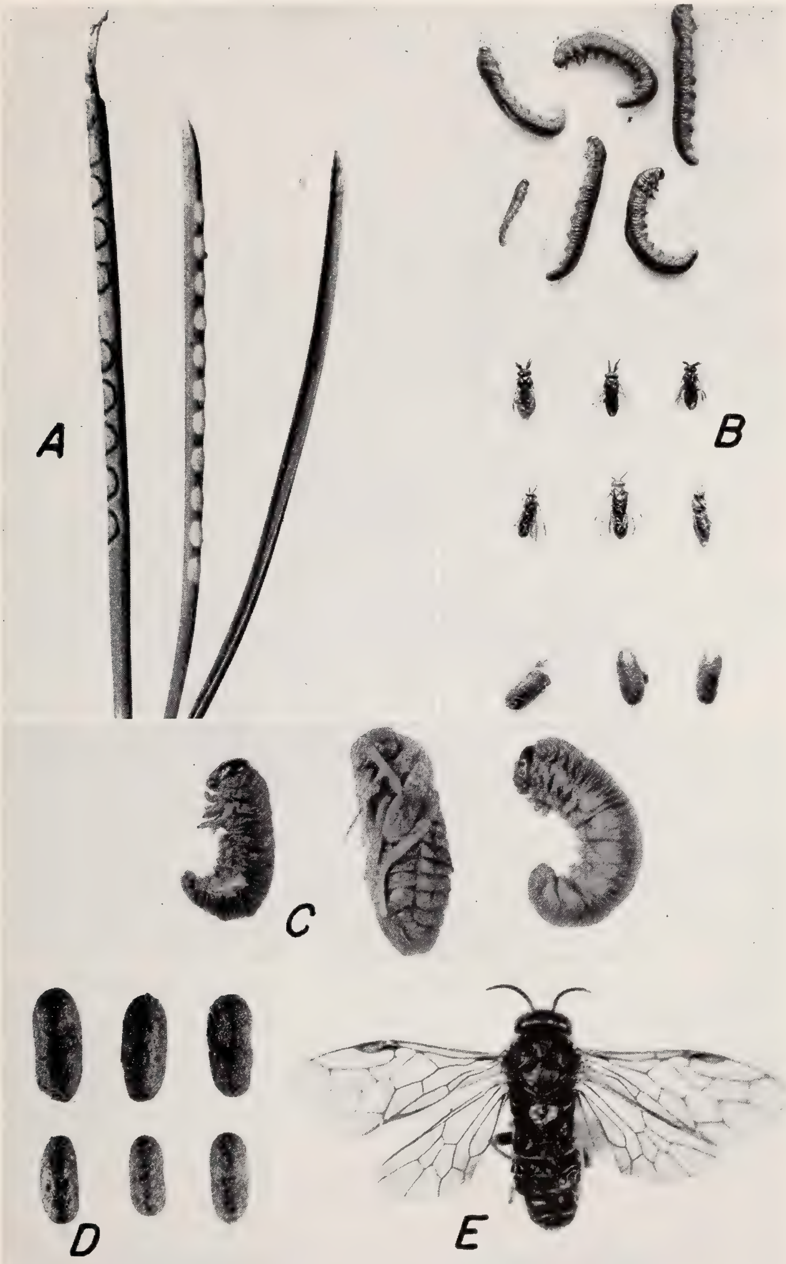

FIGURE 52.—Pine sawflies: *A*, Eggs on pine needles, × 2; *B*, larvae, adults, and cocoons of a pine sawfly, natural size; *C*, grubs and pupa, × 3.5; *D*, cocoons, × 1.5; *E*, adult of the lodgepole sawfly (*Neodiprion burkei*), × 5.

needles, leaves, or shoots. The eggs hatch in about a week, and feeding starts on the foliage. Feeding is completed by midsummer, and the slugs drop to the ground to prepare for transformation, usually spinning the tough papery cocoons. Other species pass the winter in the eggs, which hatch early in the spring, the larvae completing their feeding and transformation by fall, at which time flight and egg laying again take place.

The native sawflies are attacked by numerous parasites that play an important part in holding them in check, but weather conditions seem to be even more important in determining the number of sawflies in different seasons.

Direct control can be effected where it is practical to apply DDT or arsenical poisons, such as on shade and ornamental trees, or to forest areas by means of airplanes. Usually, however, the cost of control is not justified, because of the expense, the difficulty of applying sprays, and the fact that most outbreaks are rather quickly suppressed by natural control agencies.

In the forests of western North America there are numerous native species of sawflies, which, although usually inconspicuous in numbers, may periodically become prevalent enough to cause noticeable damage. So far, although extensive defoliations have occurred, the actual destruction of timber has been small, and the outbreaks have quickly subsided.

SAWFLIES ON CONIFERS

A number of species of sawflies belonging to several genera attack the needles of pines and other conifers. The adults are colored variously, often black or brown, and with yellowish appendages. They are usually from 1/4 to 1/2 inch long. The males frequently have large, feathery antennae while those of the females are threadlike. Eggs are laid singly, in slits made in the needles.

The young hairless larvae first feed in clusters on the nearest needles, then as they grow they scatter out over the foliage and feed singly. Upon reaching full growth, about the first of September, they are from 1/2 to 1 inch long, usually greenish, with black or brown heads, and have eight pairs of prolegs. Upon completing their feeding they usually drop to the ground and form brown, papery cocoons in the forest debris, but some may form cocoons on the needles or in crevices of the bark, while still others do not construct cocoons. The winter is usually passed in the prepupal, larval, or egg stage, and the new adults emerge the following spring. These sawflies are easily controlled where trees can be sprayed with DDT, lead arsenate, or other stomach poison.

The lodgepole sawfly (*Neodiprion burkei* Midd.) (fig. 53), in the adult stage, is about 1/3 inch long. The males are black and the females brownish. The hairless, wrinkled bodies of the larvae are greenish or grayish, with lighter lateral and dorsal stripes, brown

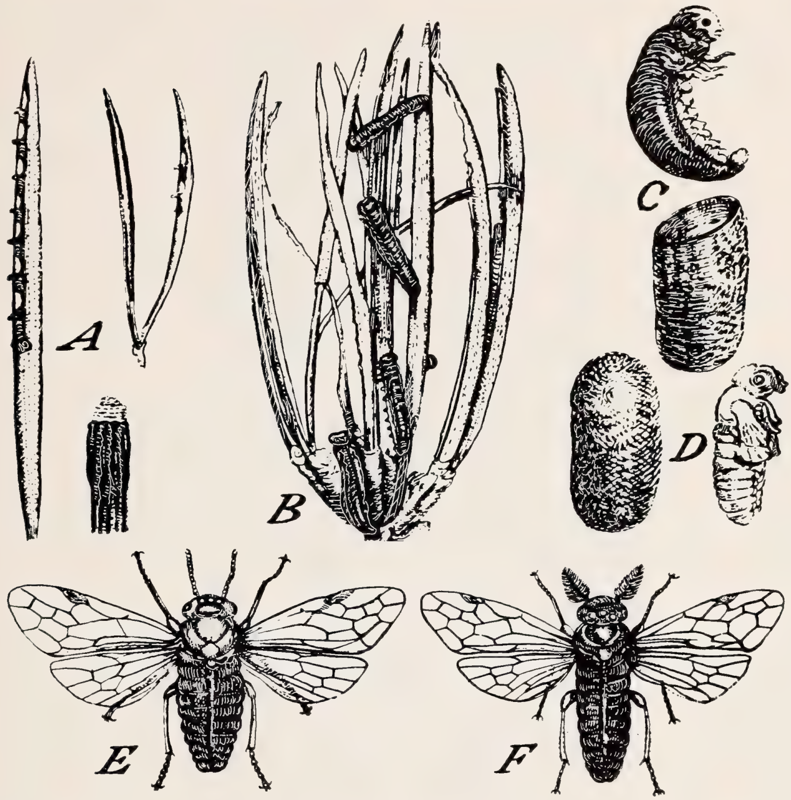

FIGURE 53.—The lodgepole sawfly (*Neodiprion burkei*): *A*, Egg pockets in needle and very young caterpillars feeding, × 1.5; *B*, larvae at work, natural size; *C*, hibernating prepupa, × 4; *D*, pupa, × 4; *E*, adult female, × 4; *F*, adult male, × 4.

heads, and black eyes, and are about 1 inch long when mature. This species developed a severe outbreak in 1921 over a large area of lodgepole pine at West Yellowstone, Mont. In the next few years a tremendous acreage of lodgepole pine was defoliated and a large percentage of the trees died. This outbreak was further complicated by a contemporary outbreak of the pine tube moth (see p. 106). Both species were controlled along highways by spraying with lead arsenate.

Another outbreak of this sawfly defoliated several hundred acres of lodgepole pine in the Klamath Marsh Basin of the Klamath Indian Reservation in 1941–45. Heavily defoliated isolated trees and less vigorous trees in the stand succumbed from repeated defoliation, but fully 90 percent of the defoliated stand recovered, although much reduced in vigor and growth rate. The species ap-

pears to be distributed through Oregon, Idaho, Montana, and Wyoming.

Other species of *Neodiprion* which feed on the needles of western pines include the following:

Species of *Neodiprion*	*Host and distribution*
americanus banksianae Roh .	Ponderosa and lodgepole pines. Idaho, Montana, and the Lake States.
edwardsii (Nort.) (*42*)	Sugar, western white, and ponderosa pines. California and Oregon.
fulviceps (Cress.)	Ponderosa pine. California, Colorado, Wyoming, South Dakota and Nebraska.
gillettei (Roh.)	Ponderosa pine. Colorado.
rohweri (Midd.)	Pinyon and singleleaf pinyon. California, Colorado, and New Mexico.

The Monterey pine sawfly (*Itycorsia* sp.) attacks only the Monterey pine in its native habitat, near Pacific Grove, Calif. The larvae are so prevalent at times as to completely defoliate the trees, either killing or seriously weakening large numbers of them. The larvae are dark green or brownish, with black heads. A characteristic of their work is that the needles are sawed off or chewed into a mass, and these broken needles and brownish excrement pellets are webbed together with silken threads.

The hemlock sawfly (*Neodiprion tsugae* Midd.) (*56*) (fig. 54) occasionally becomes epidemic and defoliates extensive areas of western hemlock in Oregon and northward into Alaska. In British Columbia and southwestern Alaska it is one of the few tree-killing insects. The adults are small—about ¼ inch long. The males are dark brown to black, the females larger and green to yellowish brown. The larvae are green and about 1 inch long when full grown. The papery cocoons are attached to the needles and to debris on the ground. There is one generation a year, eggs being laid in the needles from the middle of August to the end of September and the species overwintering in that stage. A few prepupal larvae overwinter in cocoons and some even hold over a second winter. Larval feeding and defoliation occur mainly through July and August. These sawflies are attacked by a large number of insect parasites, which normally hold the population in check.

In the northwestern part of the United States there are two native species of sawflies of the genus *Anoplonyx* (*Platycampus*) that feed on the foliage of western larch. So far they have not caused damage of economic importance.

Adults of **the two-lined larch sawfly** (*Anoplonyx occidens* Ross) are small, black, wasplike insects, a little less than ¼ inch long. The folded wings have a blue-green metallic sheen. The larvae are rather slender, about ⅜ inch long when full grown, with eight pairs of prolegs on the abdomen and are brownish-green with two narrow dark-green stripes along the sides, dark-brown heads, and black, shiny eyes. **The western larch sawfly** (*A. laricivorus* Roh. & Midd.)) closely resembles the foregoing in the adult stage, but the larvae have a single green line down the center of the back. In 1921 an outbreak of these two insects occurred throughout the

FIGURE 54.—The hemlock sawfly (*Neodiprion tsugae*): *A*, Larvae, $\times$ 1½; *B*, pupal cases; *C*, adults, natural size; *D*, defoliated western hemlock twig.

larch stands of northern Idaho and western Montana. This is the first and last record of their appearance, and, although they occurred in countless numbers in 1921, it was practically impossible to find a single larva in 1922. This is a marked example of how rapidly an outbreak can disappear. The larvae did their heaviest feeding from mid-July to the last of August, and either devoured the foliage or killed it by chewing on the fleshy portion of the needles anywhere between the tip and base. The larvae leave the trees when they are mature and spin small silken cocoons under the duff, in which they pupate. Small pebbles and grains of sand adhere to these cocoons, giving them the appearance of small lumps of dirt. The winter is passed in the cocoon, and the new

adults emerge the following spring about the time the larch foliage appears.

The larch sawfly (*Pristiphora erichsonii* (Hartig)), a native of Europe and first found in New England about 1880, has spread westward through the Lake States and Canada into northern British Columbia. Its progress has been disastrous, inasmuch as it kills trees rapidly, and has left vast areas of dead and dying larch in its wake. It was first noted attacking western larch in southern British Columbia in 1930 and since has been found in the northwestern part of the United States.

The cypress sawfly (*Susana cupressi* Roh. & Midd.) feeds on the foliage of Monterey cypress in California.

SAWFLIES ON BROADLEAVED TREES

The elm sawfly (*Cimbex americana* Leach) is commonly found in the Middle West, as well as in the Eastern States, but ranges west into Colorado and British Columbia. These sawflies are active feeders on the leaves of willow and elm, and also attack poplar, alder, maple, and other trees. The adults are large, steel blue to black, broadwaisted sawflies about 3/4 inch long with three or four yellow, oval spots on each side of the body, with short knobbed antennae, and smoky wings. They girdle the bark on twigs and kill many of them, especially in the tops of trees. The larvae are naked, wrinkled, and pale yellowish with a median black stripe down the back, and have eight pairs of prolegs. They usually lie coiled and are from 1 to 2 inches long when full grown. The adults fly in May and insert their oval eggs in the leaves. The larvae reach full growth in July or August, and overwinter in cocoons in the debris on the ground or just below the surface. Pupation occurs in the spring, only a few days before emergence and flight.

At least three other species of sawflies attack willow in the West. *Cimbex pacifica* Cress., which has habits similar to *americana,* is found in Oregon and Washington. *Cimbex rubida* Cress. is found in California and Nevada, and *Trichiosoma lonuginosa* Nort. is also found in the California and Nevada Sierras.

The cottonwood sawfly (*Pteronidea* sp.), although common, has not yet been identified specifically. The larvae, which are slender, about 1/2 inch long, green, with brown head and black eyes, and six pairs of prolegs on the abdomen, feed on the leaves of black cottonwood in northern Idaho.

LEAF BEETLES

There are a number of beetles that are leaf eaters in the larval or adult stage or in both. None of these have been responsible for any serious injury to western coniferous forest trees, but the skeletonizing and defoliation of broadleaved trees by beetles is common. Most of these beetles belong to the family Chrysomelidae. The adults of this large family of destructive beetles are small, rather short, somewhat oval in outline, and of variegated colors, some with bright metallic green or blue and others dull brown or

black. The larvae are rather stout, soft bodied, humpbacked grubs. In western forests the alder flea beetle is probably the most common representative of this family.

No control appears practical or warranted under forest conditions, but on park and shade trees leaf beetles can be controlled by spraying with powdered acid lead arsenate, 4 pounds to 100 gallons of water, as soon as the leaves unfold in the spring.

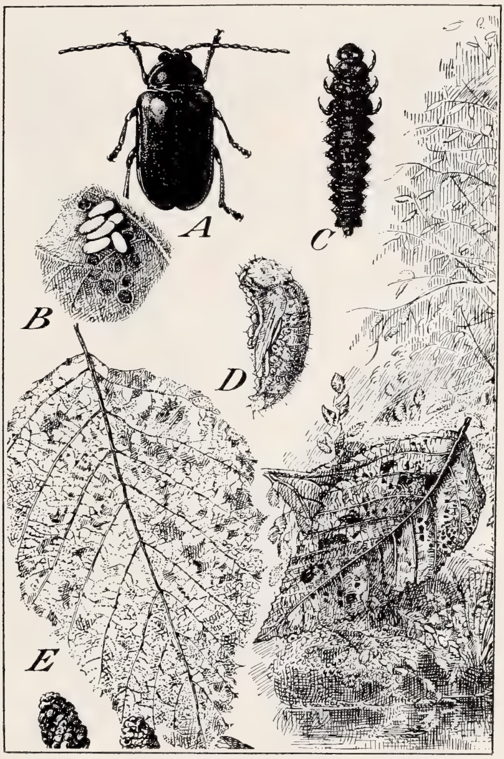

FIGURE 55.—Alder flea beetle (*Altica ambiens*): *A*, Adult beetle, × 4; *B*, eggs, × 4; *C*, larva, × 4; *D*, pupa, × 4; *E*, skeletonized leaf.

The alder flea beetle (*Altica ambiens* (Lec.)) (fig. 55) is a native species found throughout the Pacific Coast States, where it feeds on and skeletonizes the foliage of alder, poplar, and willow, both as larvae and as adults. The adults are small, dark shiny blue, and about ¼ inch long. The mature larvae are a trifle over ¼ inch long, dull brown to black, with shining black head and thorax and three pairs of short legs. The adults hibernate during the winter in debris beneath the trees and other sheltered places, appearing early in the spring to resume feeding. Clusters of yellow eggs are deposited sometime after the spring appearance of the adults. The larvae, which appear a few days later, reach maturity in August, and pupate on the ground in the duff. New adults

appear in a week or 10 days and feed voraciously on the foliage until the close of the season, when they hibernate for the winter, to appear the following spring, completing the cycle of one generation a year.

The western willow leaf beetle (*Galerucella decora* Say) is a dull yellow-brown to black native species that feeds on the leaves of willow and poplar throughout the West.

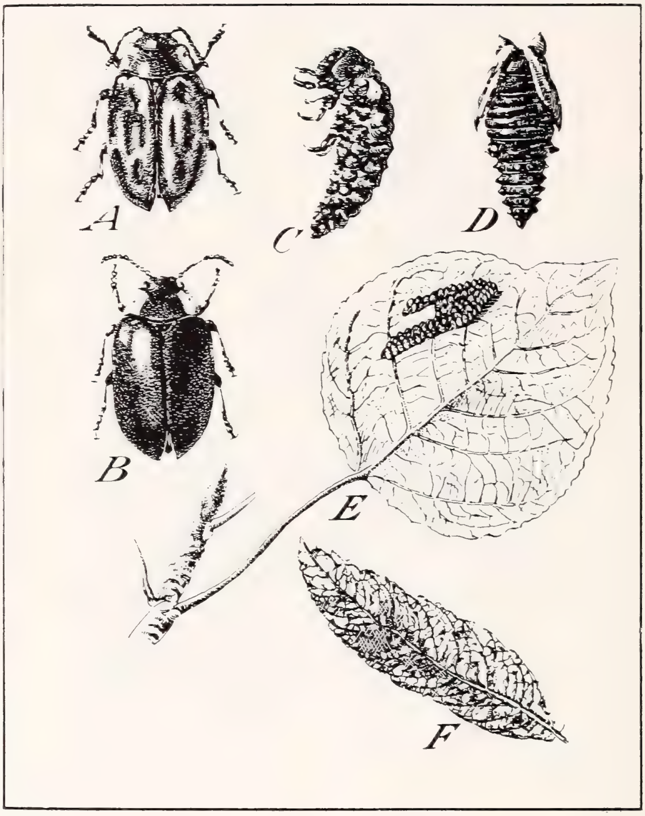

FIGURE 56.—The cottonwood leaf beetle (*Chrysomela scripta*): *A*, Female beetle, × 5; *B*, male beetle, × 5; *C*, larva, × 5; *D*, pupa, × 5; *E*, eggs on cottonwood leaf; *F*, skeletonized willow leaf.

The cottonwood leaf beetle ((*Lina*) *Chrysomela scripta* F.) (fig. 56) is found throughout the country, feeding on the leaves of willow and poplar, and often heavily defoliates these trees. The adults are yellowish marked with black spots and are about 1/4 inch long. They appear early in the spring and feed on the tender shoots. The eggs are yellowish or reddish and are deposited in clusters on the under surface of the leaves, and it is here that the black grubs feed as soon as hatched. In hot weather the period

of growth to the mature larval stage is about 15 days. Five generations a year are reported in the West. *C. tremulae* F. feeds on aspen and poplar in the Pacific Northwest and in the East.

The willow leaf beetle (*Chrysomela interrupta* F.) is similar to the above, but smaller. It feeds on willow and ranges from California to Alaska and eastward. Another species, *C. californica* Rogers, is black to bluish green and feeds on willow in California.

The spotted willow leaf beetle (*Chrysomela lapponica* L.) is sometimes as prevalent and just as injurious to willows and poplars in the Northwest as the cottonwood leaf beetle, which it closely resembles in appearance and habits. The adults are reddish, ¼ inch long, and spotted with black.

On coniferous trees colorful, squarish scarabaeid beetles of the genus *Dichelonyx* are commonly found chewing scallops along the edge of needles. *D. crotchi* Horn is a shiny green beetle about ⅜ inch long, which bites into the sides of ponderosa, Jeffrey, and lodgepole pine needles when they are about 1 inch long, causing them to drop. It is found in the mountains of California, Oregon, Washington, and British Columbia and eastward into Utah and Montana. *D. decolorata* Fall feeds on the needles of Monterey pine in California. *D. valida* Lec. is a dark blue-green species found on California laurel along the Pacific coast. *D. testaceipennis* Fall is a shiny brown species, the individuals of which feed close together on needles of white fir, Douglas-fir, and other forest trees in New Mexico.

Adult weevils of the genus *Scythropus* are often found feeding on pine needles in the spring and early in the summer. They bite out chunks and leave a saw-toothed edge. They are from 3/16 to 5/16 inch long and range in color from metallic bluish-green and gray to bronze, copper, or dark brown. **The elegant pine weevil** (*S. elegans* (Couper)) is a metallic blue-green, gold, brass, or bronze species sometimes with lighter stripes along the margins of the wing covers. It feeds on lodgepole and other pines in the northern Rocky Mountain region and in other Western States. *S. californicus* Horn is a bronze species somewhat speckled with gray, found on ponderosa, Jeffrey, digger, and other pines throughout the Pacific Coast States and the Southwest. *S. ferrugineus* Csy. is a metallic, reddish-bronze or copper-colored species, which is found on ponderosa, Jeffrey, knobcone, and Monterey pines in California and Oregon. *S. albidus* Fall is a small ashy-white weevil with a faint metallic lustre, which occurs on ponderosa and Jeffrey pines in California, Oregon, and Idaho.

Another small leaf weevil, *Thricolepsis inornata* Horn, 3/16 inch long, is mottled black and gray. Normally it feeds on oak, but sometimes nearly defoliates fruit trees close to oaks by feeding on the new leaves of opening buds. Adult weevils have been found seriously injuring tender new foliage on tips of white fir and Douglas-fir in New Mexico and southern California, ruining such trees for use as Christmas trees. It is distributed through Oregon, California, Utah, Arizona, and New Mexico.

MINERS IN THE INNER BARK AND PHLOEM

Many different species and families of insects are represented among those that select the cambium region of the main trunk of trees as a suitable place to feed. All these are chewing insects that bore under the bark and feed in the soft layers of bark and wood. As feeding progresses the channels may penetrate deeply into the sapwood or be extended into the outer bark.

Mining insects capable of attacking living, healthy trees are among the most destructive species with which the forester must deal. By far the greatest number of the cambium feeders, however, are capable of attacking only unhealthy, weakened, dying, or felled trees, and they cannot resist the copious flow of sap or resin which in the normal tree serves as a defense against attacking bark borers. At times, when a tree's resistance is low, even these normally secondary species may kill trees, if they attack in sufficient numbers.

It is easy to recognize the work of bark-feeding insects. Usually a close inspection of the trunk of an infested tree will reveal boring dust in the crevices of the bark or pitch exuding from small holes in the bark. These may or may not indicate bark-mining insects. Positive evidence of infestation can be obtained only by removing a small chip of bark and determining whether the phloem is fresh and white or discolored with the mines of some boring insects. If such mines are found, a larger piece of bark can be removed, and the species responsible for the damage usually can be identified by the character of its work.

A few species of inner-bark miners, such as the pitch moths, may work in the phloem from the edge of wounds without threatening the life of the tree, and no attempt need be made to control such species under forest conditions. Nor is it necessary to attempt any control of the vast number of inner-bark-feeding insects that confine their attack to weakened, sickly, or felled trees. Only species capable of attacking and killing living trees need cause any concern, and fortunately the number of such species is very limited. It is not difficult for the forester to learn to recognize the comparatively few phloem-mining insects that are aggressive killers of the trees in his region. Such species are discussed in detail in the following pages.

Key to the Diagnosis of Insect Injury to the Inner Bark

A. Entire tree or large part sickly, dying, or dead; foliage fading, turning yellow or red. Inner bark of main trunk and sometimes roots attacked and killed.

1. Outside of bark showing boring dust collected in crevices, small pitch tubes or both. Small egg tunnels under bark, usually of uniform width, from which extend diverging tunnels usually packed with fine borings. The egg tunnels are made by small beetles but the diverging mines are made by small, white, curled, legless larvae.................................Bark beetles, p. 129

    a. Egg galleries under bark mostly packed with boring dust and excrement; individual egg galleries (made by each pair of beetles), single, long (more than 6 inches), longitudinal, straight, crisscross, or winding, rarely transverse *Dendroctonus*, p. 131

Key to the Diagnosis of Insect Injury to the Inner Bark (Cont.)

(1) Attacking pine. Pine beetles.

(*aa*) Egg galleries very winding, transverse, sub-transverse, or longitudinal; crossing and recrossing to form network of irregular channels; eggs isolated, never in groups or masses; pupal cells in outer bark

(*aa1*) Larval mines concealed in inner bark, except for a short distance near the egg galleries, which are winding and mostly transverse or subtransverse.

Pacific coast and Northwest

Western pine beetle, (*D. brevicomis*), p. 132

Rocky Mountains and Southwest

Southewestern pine beetle (*D. barberi*), p. 133

Arizona pine beetle (*D. arizonicus*), p. 135

(*aa2*) Larval mines mostly concealed in outer bark; egg galleries mainly longitudinal.

Colorado pine beetle (*D. approximatus*), p. 135

(*aa3*) Larval mines exposed in inner bark; egg galleries mainly longitudinal.

Roundheaded pine beetle (*D. convexifrons*), p. 134

(*bb*) Egg galleries nearly straight to slightly sinuous, longitudinal (following the grain), and long (more than 10 inches), with L-shaped curve near entrance; larval mines short and broad and usually exposed in inner bark; eggs deposited singly or in small groups along egg galleries.

Pacific coast, Northwest, and northern Rocky Mtns... Mountain pine beetle (*D. monticolae*), p. 135

Rocky Mountains and Southwest

Black Hills beetle (*D. ponderosae*), p. 139

California—Jeffrey pine

Jeffrey pine beetle (*D. jeffreyi*), p. 140

(*cc*) Egg galleries broad, irregular in width; eggs deposited in masses; larval mines contiguous, forming a broad larval chamber under bark at base of trunks or in stumps; large masses of pitch at entrance holes.

North America—in all pines

Red turpentine beetle (*D. valens*), p. 142

Northern Rocky Mountains—in lodgepole pine

Lodgepole pine beetle (*D. murrayanae*), p. 141

(2) Attacking other conifers; egg galleries straight to slightly winding, longtudinal, and usually short; eggs placed in distinct alternate groups; larval mines long.

(*aa*) Larval mines separate throughout entire length; egg gallery averaging 8 to 16 inches long. Found in Douglas-fir, western larch, and sometimes western hemlock. Douglas-fir beetle (*D. pseudotsugae*), p. 155

(*bb*) Larval mines near egg gallery merging; in spruces.

Rocky Mountains and west

Engelmann spruce beetle (*D. engelmanni*), p. 163

Alaska and Canada

Alaska spruce beetle (*D. borealis*), p. 164

North Pacific coast

Sitka spruce beetle (*D. obesus*), p. 164

b. Egg galleries under bark not packed with boring dust; individual galleries consisting of one or two short (less than 6 inches) tunnels with entrance and nuptial chamber central or at one end.

Key to the Diagnosis of Insect Injury to the Inner Bark (Cont.)

(1) In coniferous trees

(*aa*) Dark reddish brown to black, shining beetles with undercut abdomen; make one or two short longitudinal or transverse egg tunnels from a well-defined central nuptial chamber; in fir, spruce, hemlock, or Douglas-fir. .*Scolytus*, pp. 157, 165, 166, 167

(*bb*) Dull, dark-brown, roughened beetles with rear of abdomen rounded; make one or two short longitudinal or transverse egg tunnels without a well-defined nuptial chamber.

(*bb1*) In moist bark at base of pines. . .*Hylastes*, p. 154
Hylurgops, p. 154

(*bb2*) In true firs, hemlock, spruce, Douglas-fir, or pines.
Pseudohylesinus, pp. 154, 155, 161, 162, 165, 166

(*cc*) Small stout, dull brown to black beetles, with rounded abdomen; make one (sometimes two) short, longitudinal egg tunnels with well-defined nuptial chamber at base; in cedar, cypress, redwood, and other cupressine trees. . . .*Phloeosinus*, p. 167

(2) In broadleaved trees

(*aa*) Egg galleries transverse (across the grain), short, nearly straight.
In oak. .Oak bark beetle, *Pseudopityophthorus*, p. 169
In ash. . . . . .Ash bark beetle, *Leperisinus*, p. 169

(*bb*) Egg galleries longitudinal (with the grain); without enlarged entrance chamber.
In alder. . . . .*Alniphagus*, p. 169

c. Egg galleries under bark not packed with boring dust; individual galleries consisting of two or more tunnels forking or radiating from a central entrance and nuptial chamber.

(1) Egg galleries forking from a central nuptial chamber with branches nearly straight and parallel (except at start); mines 1/16 inch or more in width.

(*aa*) Egg tunnels forking longitudinally; brood chambers exposed in inner bark; cylindrical beetles with spines around a concavity on the rear of the wing covers. . . . .*Ips* (in part), pp. 144-151

(*bb*) Egg tunnels forking transversely; brood chambers concealed in inner bark. . . . . . .*Polygraphus*, p. 166

(2) Egg galleries radiating from central nuptial chamber with branches slightly to strongly curved and not parallel to each other.

(*aa*) Large species; mines 1/16 inch or more in width.

(*aa1*) Nuptial chambers scoring the sapwood
Ips (in part), pp. 151, 152, 165

(*aa2*) Nuptial chamber not scoring the sapwood.
Galleries mainly longitudinal.
Dryocoetes, pp. 163, 165
Galleries mainly transverse. *Polygraphus*, p. 166

(*bb*) Small species; mines less than 1/16 inch in width; enlarged nuptial chamber; larval mines short and club-like.

(*bb1*) Under thick, dry bark, mines often crossing those of *Dendroctonus*. . . . . .*Orthotomicus*, p. 153

(*bb2*) Under thin bark; pines. . . . . . .*Pityogenes*, p. 152

2. Bark showing no outward sign of insect attack. Tunnels under bark and sometimes entering wood; these increase in size with the growth of the white, often legless grubs which make them.

Key to the Diagnosis of Insect Injury to the Inner Bark (Cont.)

a. Mines flattened, oval in cross section usually, packed with arclike layers of boring dust made by slender grubs shaped like horseshoe nails; first thoracic segment greatly enlarged and flattened, with a horny plate on both top and bottom
Flatheaded borers, p. 169

b. Mines broadly oval in cross section, made by elongate grubs which are thick in front with tapering bodies, thoracic segments enlarged, with horny plate on top only
Roundheaded borers, p. 173

c. Mines round in cross section ending in pupal cells partly in the wood, often lined with shredded wood fibers. Usually at base, root collar, or roots of weakened trees. Sometimes in terminals and twigs........................Bark weevils, p. 176

B. Tree apparently healthy or in some cases top-killed. Large masses of pitch exuding from wounds on trunk or with the bark, on a dying top, appearing pitchy and dry, and separating from the wood as though scorched. Slender caterpillars with three pairs of legs found working in the pitch........................Pitch moths, p. 178

BARK BEETLES

The common term "bark beetle" (*32, 88, 150*) is applied to a group of small beetles belonging to the family Scolytidae. They are the most destructive group of insects to be found associated with western coniferous forests. Recent estimates place the annual loss of timber in the Western States as a result of their activities at 2.8 billion board feet. The bulk of this destruction is caused by five species of *Dendroctonus*—the western pine beetle, the mountain pine beetle, the Black Hills beetle, the Douglas-fir beetle, and the Engelmann spruce beetle.

The bark-beetle adults are small, cylindrical insects, ranging in size from the tiny *Crypturgus,* about $\frac{1}{20}$ inch long to the larger species of the genus *Dendroctonus,* which attain a length of approximately $\frac{3}{8}$ inch. Most species are unicolored, dark brown, reddish brown, or black, and are either shining or dull, though a few species have variegated markings. The head, which is more or less hidden by the thorax, has chewing mouth parts, with well-developed mandibles.

The adults of cambium-mining bark beetles have the very distinctive habit of boring through the bark and making a tunnel between bark and wood in which to lay their eggs. The complete work or engraving of the bark beetles is therefore characterized by having two types of tunnels—egg galleries, made by parent adults, and larval mines, formed by the growing larvae. These tunnels form a particular pattern on the inner surface of the bark, which is distinctive for each species and usually very similar for each genus.

In starting an attack the male or female beetle bores an entrance tunnel through the bark, usually at a slightly upward angle. An egg tunnel is then constructed along the surface of the wood, cutting through the inner bark and often slightly or deeply scoring the sapwood. As the work progresses, fine boring dust and excrement are extruded through the entrance hole and collect in the bark crevices. In some cases pitch and sap exude from the entrance

hole and harden on the bark in various forms of pitch or resin tubes. Some species construct ventilation tunnels at intervals along the egg galleries. These are perpendicular to the egg galleries and extend through the bark to the surface or may end before the surface is reached. Boring dust is pushed out of those that are open at the surface of the bark, and they all are probably used as turning niches, as well as for ventilation of egg tunnels. Later, as the mines progress, these are sometimes plugged with boring dust.

The eggs, which are very small, are oval, round, or slightly elongate, and clear or chalky white. They are deposited in small cup-shaped cavities along the sides of the egg galleries. Usually a single egg is placed in each cavity or egg niche, which is closed with a plug of boring dust in such a way that the smooth cylindrical egg gallery is but little altered. Some species cut larger cavities or egg pockets and deposit from two to eight eggs in each. Others cut an elongated groove on one or both sides of the egg gallery and deposit the eggs in layers or rows.

The larvae, or grubs, are thick-bodied, always legless, cylindrical and curved, white or cream colored, with a distinct head and prominent dark-colored mandibles. At first the larvae and their mines are very small, but both increase in size as feeding progresses. The larval mines start away from the egg gallery more or less at right angles and may continue nearly straight or turn and run parallel to the egg tunnel. They are always packed with excrement and boring dust.

Transformation to the pupal stage takes place at the end of the larval mine in a specially constructed pupal cell. The pupae are soft, white, and unprotected. The antennae, mandibles, legs, and wing pads are clearly visible, and hairs and spines are often present on the various regions of the body. Gradually the pupae darken, turning light yellow and then brown, as the adult form is reached.

The adults, after a short hardening period, emerge and fly to attack new host trees, or congregate in cavities under the bark of the old host tree, or drop to the ground to hibernate. Some adults do a certain amount of feeding under the bark before emerging, and food tunnels made in this way are quite distinct in character from the regular egg galleries. Others upon emerging feed upon twigs or buds of other trees before again attacking the bark of a new host.

Normal or endemic infestations of bark beetles are present in practically all mature forests (*151*), causing an annual loss of a fraction of 1 percent of the timber on the area. Under conditions favorable to the insects, serious epidemics develop from these normal infestations in a very few years. Such outbreaks may be of short duration, or they may continue for many years, destroying large volumes of merchantable timber over extensive acreages.

If bark-beetle attacks are to be successful, the attacking insects must be present in sufficient numbers to overcome the resistance of the tree. Dead and dying trees offer little resistance to attack and for this reason they are usually chosen by the secondary species

that are not capable of coping with a vigorous pitch flow. Light attacks by primary species on living trees often fail because the flow of pitch is so copious that the attacking beetles are overcome or driven from their galleries. The oleoresins are known to be repellent and toxic to the beetles and so aid in resisting light attacks.

In the following discussion the bark beetles attacking western forest trees will be treated under their principal host trees.

PINE BARK BEETLES

No group of commercially valuable trees in western forests has more insect enemies than the pines, and of these, bark beetles are the most numerous and destructive. The most aggressive bark beetles attacking western pines are the so-called pine beetles, which belong to the genus *Dendroctonus*. Several species in this group are capable of attacking and killing normal healthy trees. The damage they do in western pine forests runs into millions of dollars annually (*87*).

The next most important group comprises the pine engraver beetles belonging to *Ips, Pityogenes,* and related genera. These beetles usually work under thinner bark and make very striking and distinctive forked or star-shaped gallery patterns. While they normally breed in weakened, dying, or felled trees, or in broken branches and slash, and are to that extent beneficial in hastening the disintegration of forest debris, they occasionally develop in sufficient numbers to become primary enemies of young trees and of the tops of older ones.

There is also a third group of bark beetles comprising a large number of species that are secondary in their attack and are seldom responsible for the death of any trees. Many of these are found feeding under the dying bark of pines that are being killed by other bark beetles, fire, or other causes, and sometimes are confused with primary species. Space will not be taken for a description of all the bark beetles that may be encountered, for it is usually sufficient for all practical purposes if the forester learns to recognize species of chief importance.

Dendroctonus Beetles

The pine beetles that are members of the genus *Dendroctonus* (meaning tree killers) (*72*) make up by far the most destructive group of bark beetles attacking pine trees in North America. All species breed under the thick bark of the trunk of living or dying trees or in fresh stumps or logs of various pines. Some species prefer felled, weak, or dying pines, whereas others apparently prefer normal, healthy pines for their attack.

The adults are stout, cylindrical, dark, reddish-brown to black bark beetles ranging from 1/8 to about 3/8 inch long. The eggs, larvae, and pupae are similar to those of other bark beetles. These beetles are monogamous in habit and each pair constructs a single egg gallery which, starting from the outside, penetrates to the cambium and is extended between the bark and wood. Egg gal-

leries differ in that some wind in a tortuous manner, crossing and recrossing the galleries made by other pairs of beetles, while others are straight and parallel to the grain of the wood. *Dendroctonus* egg galleries are always packed with boring dust, except for an inch or two at the end where the beetles are working. This will distinguish the work of the *Dendroctonus* beetles from that of other groups of bark beetles.

Trees attacked by *Dendroctonus* beetles can first be distinguished by reddish boring dust caught in bark flakes or crevices and around the base of the tree, or by pitch tubes that form on the bark at the mouth of the entrance tunnels, but in heavily attacked or decadent trees pitch tubes are often either missing or so small that they can be seen only from a short distance. Later, discoloration of the foliage furnishes a more noticeable evidence of attack. It is difficult, however, to correlate accurately the discoloration with the status of brood development, as this varies with different tree species, regions, and seasons. The most conclusive evidences of attack are the egg and larval galleries on the inner surface of the bark. These form a pattern so characteristic for the work of each species that, when considered with locality and host tree, the identification of the species responsible for the attack is relatively simple.

The western pine beetle (*Dendroctonus brevicomis* Lec.) (*31*) is the most important insect enemy of ponderosa and Coulter pine within the range of these trees from Baja California north into Oregon, Washington, Idaho, Montana, and western Canada. Other pines may be attacked under exceptional conditions. Normally this beetle breeds in a few overmature trees, in windfalls, unhealthy trees, or in trees weakened by drought, stand stagnation, or fires. Under epidemic conditions it becomes aggressive and kills apparently vigorous trees of all age classes having bark sufficiently thick to protect the insect in its development. Trees under 6 inches in diameter are seldom attacked, nor does this beetle breed in limbs. The heaviest losses of mature merchantable ponderosa pine have resulted from outbreaks of this insect in California, Oregon, and Washington. It is less important in the more northern limits of its range. Losses as high as 50 percent of the timber in 5 years have been recorded, and many large blocks of pine timber have been commercially ruined by its depredations (fig. 57).

The adult beetles are about the smallest of the western species of *Dendroctonus* and measure from 1/8 to about 1/5 inch long. The larvae found in the outer bark are white, curved, and about the size of a grain of rice. Their work is distinguished from that of other bark beetles within the same range by the winding egg galleries which cross and recross each other, forming a network of irregular markings on the inner surface of the bark and on the surface of the sapwood (fig. 58). The larvae feed in the inner bark, working away from the egg gallery for about half an inch and then turn into the outer bark, where they complete their development. Flight and attacks start late in the spring or early in the summer and continue until stopped by cold weather. There are

FIGURE 57.—A bark-beetle-infested ponderosa pine stand in California. Light areas show trees killed in one year by the western pine beetle.

from one to two generations annually in the northern part of the range and from two and one-half to four generations in the southern portion, where activity continues almost without interruption throughout the year.

Woodpeckers, clerid beetles, and ostomatid beetles are important natural enemies of this insect, though its abundance is more often determined by climatic influences and the resistance of the host tree. Prolonged winter temperatures of −20° F. and lower have been found to cause heavy brood mortality. Rapid, vigorous tree growth increases host resistance and discourages epidemics.

This bark beetle has been most successfully controlled through sanitation-salvage logging, by which high-risk trees are removed from the stand and utilized for lumber, thus depriving the beetles of susceptible host material. Direct control may be recommended, particularly for parks and recreational areas, when epidemics appear to be developing, and for maintenance control. Direct control measures consist in felling the infested trees, peeling, and burning the bark late in the fall, or in winter or early spring. Such control work has been successful in reducing infestations during critical periods, but cannot be relied on to eliminate them and must be repeated until natural control factors become operative.

The southwestern pine beetle (*Dendroctonus barberi* Hopk.) attacks ponderosa pine in southern Colorado, southern Utah, Arizona, and New Mexico. A preference is shown for trees over 6 inches in diameter and for those that, owing to drought or other causes, are in a weakened condition. It is most frequently found attacking mature, slow-growing trees on the lower fringe of pine growth and trees exposed on rocky ridges and dry southern slopes. This insect and the pattern of its galleries can scarcely be dis-

FIGURE 58.—Typical winding egg galleries of the western pine beetle marking the surface of ponderosa pine sapwood.

tinguished from those of the western pine beetle, and the methods of control are the same. Since this beetle is less aggressive than the western pine beetle, control measures are seldom required.

The roundheaded pine beetle (*Dendroctonus convexifrons* Hopk.) attacks ponderosa pine throughout the same range as the southwestern pine beetle and often in company with it. This species usually enters the lower portion of trees previously infested by other bark beetles, but is sometimes primary in its attack upon decadent or weakened trees. The adults are about 1/4 inch long and are a dark, shiny brown or black. The egg galleries are mostly

vertical, long, slightly to markedly sinuous. The larval mines are usually in the cambium; pupation may take place either in the inner bark or concealed in the outer corky bark. Normally there is but one generation a year, and since the emergence is extended throughout most of the season there are never any great numbers of beetles attacking at any one time. The species is usually secondary and relatively unimportant.

The Arizona pine beetle (*Dendroctonus arizonicus* Hopk.) attacks and kills ponderosa pine and Apache pine in central Arizona and probably other parts of the Southwest. Its appearance and habits are very similar to those of the southwestern pine beetle, and the methods of control are the same.

The Colorado pine beetle (*Dendroctonus approximatus* Dietz) attacks ponderosa, Arizona, and probably other pines in its range from northern Colorado and southern Utah south through Arizona and New Mexico. The dark-brown, elongate adults are from 1/8 to about 1/5 inch in length. They excavate a network of long, longitudinal, diagonal, and sometimes transverse galleries between the bark and wood of dying, felled, and occasionally of healthy trees. The brood galleries are distinguished from those of most other species by the fact that the eggs are deposited in large niches on the side of the gallery farthest from the wood, rather than on the other sides of the gallery. Its work is therefore characterized by the absence of exposed larval mines on the inner surface of the bark. There is only one generation annually, and as a consequence it is not an aggressive species nor one of economic importance.

The mountain pine beetle (*Dendroctonus monticolae* Hopk.)

FIGURE 59.—Lodgepole pine stand killed by the mountain pine beetle.

(*44, 49, 78*) is very destructive to pines in the high mountains of California, Oregon, Washington, western Nevada, Idaho, western Montana, northwestern Wyoming, and British Columbia. In many places it has all but wiped out thousands of acres of lodgepole and western white pine (fig. 59), taken a heavy toll of valuable sugar pine, and attacked and killed ponderosa pine, white-bark pine, and many other species of pine within its range. Even fir, spruce, and hemlock may be attacked when near groups of heavily attacked pines. Trees from 4 to 5 inches in diameter up to those of the largest size may be attacked. Attacks are usually heaviest

FIGURE 60.—Long vertical egg galleries are characteristic of mountain pine beetle work.

along the main trunk of a tree from within a few feet of the ground up to the middle branches but may extend from the root collar very nearly to the top and into the larger limbs. During endemic infestations there is a tendency for the beetles to select the weaker, less vigorous trees for attack, but no such selection is apparent during epidemic conditions. Infested trees are recognized first by pitch tubes on their trunk and red boring dust in bark crevices and on the ground at the roots; later, by discoloration of the foliage, as it changes from normal green to light greenish yellow, and then to red.

The adults are rather stout, black, cylindrical beetles from $\frac{1}{8}$ to $\frac{1}{5}$ inch long. They excavate very long, perpendicular egg galleries (figs. 60 and 61) through the inner living bark, engraving both bark and wood. The galleries may be nearly straight or slightly sinuous, and sometimes, particularly in sugar pine, decidedly winding, and at the bottom of these galleries there is a short crook, or bend, 1 or 2 inches in length. The perpendicular portion of the gallery ranges in length from 12 to 36 inches and nearly always follows the grain of the wood.

Eggs are deposited singly in cells or egg niches on alternate sides during the construction of the egg gallery. These hatch in a few days, and the small white larvae excavate short feeding tunnels at right angles to the egg gallery. These feeding tunnels vary in length and are exposed on the inner bark surface. When full grown, the larvae construct small pupal cells at the ends of the larval mines and in these transform to pupae and then to new adults. These pupal cells are usually exposed when the bark is removed, but in thick-bark trees they may be concealed in the inner bark. The new adults may bore away the intervening bark between pupal cells and congregate beneath the bark, prior to emergence, or individual emergence holes may be constructed directly from the pupal cells. Two or more insects often use the same emergence hole, and the emerging beetles often take advantage of cracks in the bark or in holes resulting from woodpecker work.

The mountain pine beetle passes the winter in all stages of development except the pupa. The overwintering broods emerge in three well-defined groups, (1) in June, (2) late in July and early in August, and (3) in September. New attacks are made immediately after emergence, and the resultant broods develop to new adults, mature larvae, or small larvae before cold winter weather again stops development. Normally there is only one generation a year; but, owing to the uneven development, there is considerable overlapping of the various broods, so insects in all stages may be found at any time during the summer. Late fall, winter, or early spring is therefore the best time to carry on control work.

A clerid beetle (*Enoclerus*), a fly (*Medetera*), and a parasitic wasp (*Coeloides*) are the most active insect enemies of this pine beetle. Woodpeckers also prey upon the species, and climatic conditions often are important as natural control agencies.

Direct control methods vary with the region and character of in-

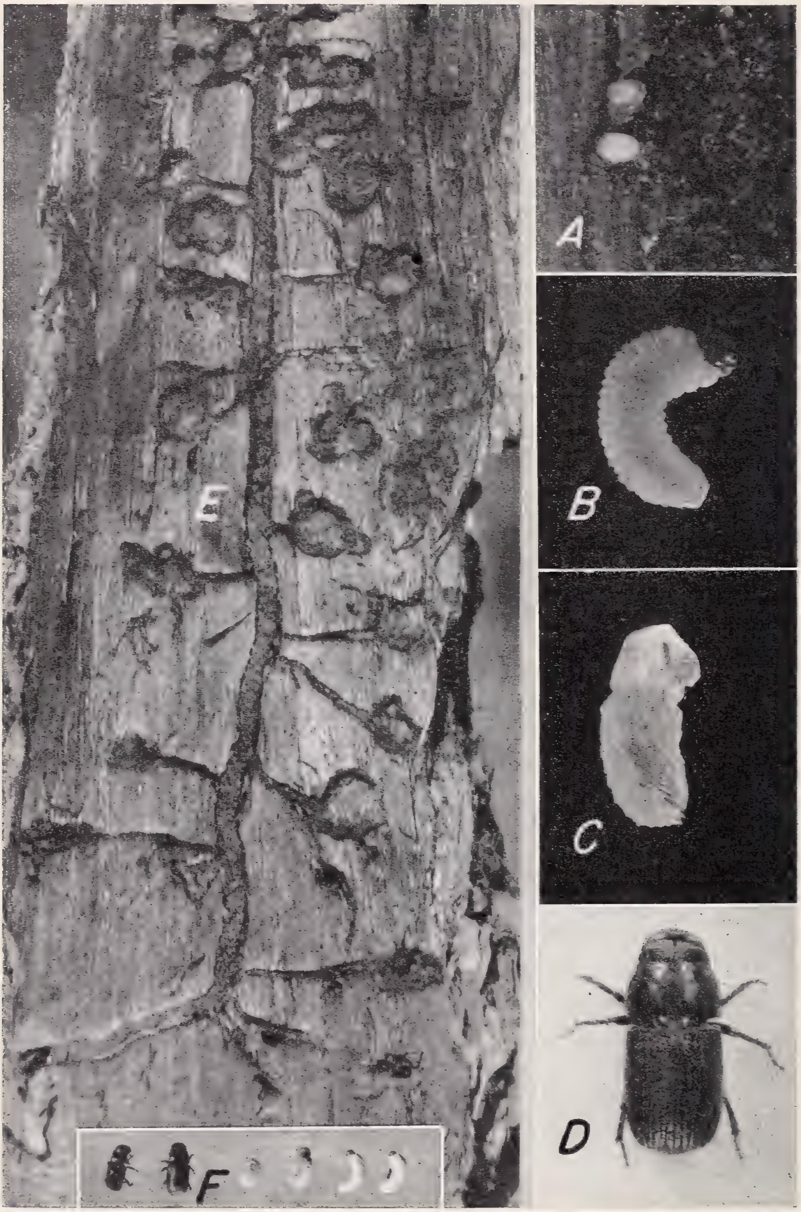

FIGURE 61.—Stages and typical work of the mountain pine beetle (*Dendroctonus monticolae*): *A*, Eggs, greatly enlarged; *B*, larva; *C*, pupa; *D*, adult; *E*, typical gallery; *F*, adults, pupae, and larvae. *A-D*, × 4; *E* and *F*, natural size.

fested timber, particularly whether the trees are thin-barked, such as lodgepole pine, or thick-barked, as sugar pine. The more commonly used methods include (1) felling the infested trees and burning the bark either on or off the trunk; (2) felling trees and peeling the bark to expose the immature broods; (3) felling and sun-curing; (4) spraying trees with fuel oil and burning them either after felling or while standing; and (5) spraying trees with penetrating petroleum oils to which a toxicant such as orthodichlorobenzene, DDT, benzene hexachloride, or chlordane has been added, either after felling or while the trees are still standing.

For sugar pine the usual method is felling, peeling the top half of the log, and burning the lower half. Burning can be continued until the start of emergence or until the fire hazard becomes too great. Peeling can be used on white pine, the bark of which slips easily; but peeling becomes ineffective after the broods start to pupate. Nearly all methods are applicable to treatment of lodgepole pine. In the southern part of its range broods can be destroyed with the sun-curing method by felling the trees, trimming off the branches, and exposing the trunk to the sun's rays; then, after a few days' exposure, rolling the logs to expose the under half. Control operations for the mountain pine beetle are usually undertaken in the spring.

The Black Hills beetle (*Dendroctonus ponderosae* Hopk.) (*9, 10, 11, 14*) is the most aggressive and destructive insect enemy of ponderosa pine in the Rocky Mountain region. It is distributed from the Black Hills of South Dakota to eastern Montana and south through eastern Wyoming, Colorado, Utah, Arizona, and New Mexico. Under normal conditions it is comparatively rare and found only in weakened, decadent trees. Periodically, however, its numbers increase to epidemic proportions and these sweep through the ponderosa pine stands, killing small to large groups in ever-increasing numbers, until as much as 50 to 90 percent of the stand may be killed over large areas (fig. 62). Under such conditions it shows little discrimination and will attack and kill trees of all sizes, except the very smallest, apparently without regard for their health or vigor. Infested groups may contain from 2 or 3 to as many as 350 or more trees, and the size of the groups is a good indication of the severity of the infestation. On the edge of large groups there will nearly always be "pitched-out" attacks, indicating insufficient numbers in the attacking force. While ponderosa pine is the favored host, the beetles, particularly when epidemic, will attack all other pines within their range, such as lodgepole, limber, bristlecone, and pinyon, and occasionally spruce. This beetle is so similar to the mountain pine beetle in appearance, habits, and character of work as to be scarcely distinguishable from it (fig. 61).

The Black Hills beetles pass the winter as young to full-grown larvae and parent adults under the bark of trees attacked the previous season. The new brood of adults emerges late in July and in August, with some stragglers emerging in September. There is but one generation a year.

Direct control methods consist of (1) felling the infested trees

FIGURE 62.—Light-colored treetops show severe damage by the Black Hills beetle to ponderosa pine in the Kaibab National Forest, Ariz.

and peeling the bark, (2) decking trees into piles and burning them, or (3) spraying felled or standing trees with toxic penetrating oils. This work usually is done late in the spring or in the summer until mid-July. Peeling becomes ineffective as soon as new callow adults have formed. Burning can be carried on later, but should be halted on the approach of fire weather. Spraying standing trees with a mixture of 6 parts of fuel oil and 1 part of orthodichlorobenzene was the method used in 1948 on a large control project in the Black Hills of South Dakota.

The Jeffrey pine beetle (*Dendroctonus jeffreyi* Hopk.) is an aggressive and at times very destructive enemy of Jeffrey pine in California. Although it often attacks apparently healthy growth, it seems to prefer trees that are retarded in growth by drought or defoliation. It rarely attacks felled trees, so does not breed in slash or windfalls to any extent. It confines its attacks to Jeffrey pine, and its distribution is therefore limited to that of its host tree (*99*).

The work of this beetle (fig. 63) is very similar to that of the mountain pine beetle. Reddish pitch tubes form at the mouth of the entrance holes, which are usually in crevices of the bark. There is usually a slight turn at the bottom of the egg gallery, which then proceeds up the tree in nearly a straight line following the grain of the wood. These galleries are usually 2 or 3 feet in length and are packed with boring dust. The eggs are placed in niches along the sides of the galleries, and the larvae work out from the egg gallery across the grain of the wood. The pupal cells are formed in the inner bark and are exposed to view when the bark is removed. The adults are black and about ¼ inch long, and similar to, but considerably larger than the mountain pine beetle.

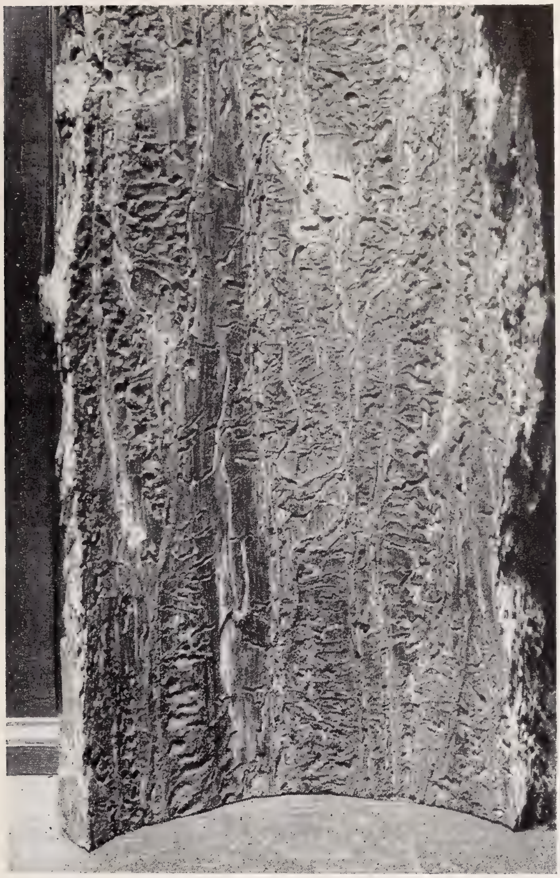

FIGURE 63.—Tunnels of the Jeffrey pine beetle on the inner bark surface of Jeffrey pine.

Trees are attacked most frequently in July or August. Eggs are laid, and some of the insects reach the new adult stage by winter. Parent adults, larvae, and new adults spend the winter under the bark. In the spring, development continues, most of the new broods emerge in July and August, and thus there is ordinarily only one generation a year.

Either peeling the bark from infested trees before new adults form, or burning it, will kill the Jeffrey pine beetle. Methods used for the control of the western pine beetle are usually employed for this species also.

The lodgepole pine beetle (*Dendroctonus murrayanae* Hopk.) develops in large numbers in freshly cut stumps and attacks the base of old, weakened lodgepole pine in eastern Washington, Idaho, Montana, Wyoming, and Colorado. Ordinarily not an aggressive enemy, it occasionally kills overmature lodgepole pines left standing after tie operations, timber sales, or other cuttings. Fortu-

nately such outbreaks die down at the close of the operation. Sometimes trees are killed the first year by the basal attacks of the lodgepole pine beetle, or it may require 3 or 4 successive years of attack before the resistance of the trees is sufficiently lowered to render them attractive to other bark beetles. Other trees are abandoned by the insects before the attacks prove fatal. In any case, this basal damage to the tree may be considered as primary, as it is the first weakening influence.

The adults are about ¼ inch long and have reddish wing covers, while the prothorax and head are dark brown or black. Their attacks, which are made on stumps or on the boles of the trees, usually within 4 or 5 feet of the ground, are easily recognized by the large pitch tubes, an inch or more in diameter, which form at the entrance holes. On reaching the cambium the attacking beetles construct short egg galleries, ranging from 5 to 12 inches or more in length, directly between the bark and wood. Eggs are deposited along the sides of these galleries and are separated from one another by boring dust. The larvae feed away from the egg gallery, keeping together in a common excavation or brood chamber. There are no separate or individual larval mines. Transformation to pupae and new adults takes place in cells constructed in the uneaten part of the inner bark or in cocoonlike structures composed of excrement in the brood chamber. The seasonal history has not been thoroughly worked out, but there appears to be one generation a year. Outbreaks of this insect are seldom of sufficient economic importance to warrant control measures.

The red turpentine beetle (*Dendroctonus valens* Lec.) (fig. 64) (*43, 60*) attacks the base of injured, dying, or healthy trees, or freshly cut logs and stumps of all pines and occasionally spruce, larch, and fir, throughout the western and northeastern parts of the United States and southern Canada. Ordinarily it is not considered an aggressive tree killer but it does do considerable primary damage and so weakens trees as to make them more susceptible to attack by other bark beetles. In some infestations, as in Monterey pine in California, it causes sufficient damage to kill the tree. It is particularly active around logging operations, where it not only works in the stumps, but often produces catfaces on the bases of trees left in the reserve stand.

The adults are the largest bark beetles of this genus, measuring from ¼ to ⅜ inch long, and are distinctly reddish in color. They are often called barber beetles by woodsmen, because of their ability to clip hairs, and are commonly, though erroneously, thought to be the bark beetles responsible for the destruction of pines. Their attacks are characterized by large reddish pitch tubes that form at the point of attack. On burrowing under the bark, the beetles excavate irregular longitudinal egg galleries between the bark and the wood. These galleries range from a few inches to several feet in length, as Patterson reports finding one gallery extending underground along a root for 15 feet from the point of entrance. The galleries are more or less packed with frass, and eggs are laid in groups or masses at intervals along the sides. The larvae feed out through the inner bark in mass formation, produc-

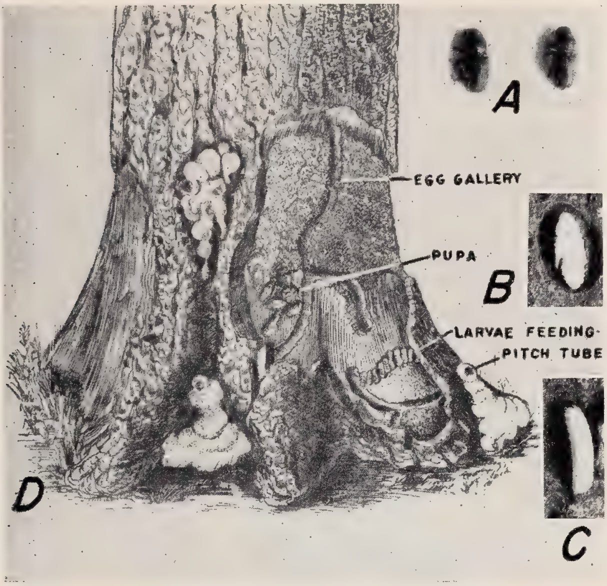

FIGURE 64.—The red turpentine beetle (*Dendroctonus valens*): *A*, Adults; *B*, pupa; *C*, larva (all natural size); *D*, base of infested tree showing characteristic work.

ing a cavity ranging from a few square inches to a square foot or more in area, between the bark and wood. These chambers are often filled with a resinous liquid that apparently has no injurious effect on the developing broods. Transformation to the adult stage occurs within pupal cells constructed in the boring dust of the brood chamber or in short mines along its margin.

There may be one or more generations annually, depending on locality and season. In the more southern range of the beetle it can be found in all stages of development at nearly any season of the year. The heaviest attacks occur in midsummer, and the winter is passed as larvae, new adults, and parent adults, in trees and stumps attacked the previous season.

Though this beetle is seldom of serious importance in commercial timber stands, should control measures become necessary, the broods can be destroyed by removing the bark from fresh stumps and from the base of infested trees. For the protection of individual park or shade trees, the damage can be halted by cutting out the attacking beetles with a knife or chisel as soon as pitch exudations indicate their presence. Successful control also has been obtained by injecting carbon disulfide into the galleries.

Pine Engraver Beetles

Smaller species of bark beetles, which work in the trunks and larger branches of pines and construct egg galleries that radiate from a central nuptial chamber and form distinctive patterns, are

frequently referred to as the pine engraver beetles. These belong to *Ips, Pityogenes, Orthotomicus,* and related genera.

These bark beetles normally feed on the cambium of weakened, dying, or recently felled coniferous trees and are capable of developing in large numbers in such material as windfalls, snowbreak, logging and road slash, and also the tops of trees killed by *Dendroctonus* or other beetles. They are beneficial insofar as they help in the reduction of forest debris, but if large quantities of favorable host material are avaliable they frequently develop and emerge in such numbers as to attack and seriously injure or kill adjacent groups of healthy trees. Under such conditions they are often exceedingly destructive to seedlings, saplings, and young second-growth poles, and the tops of older trees. While *Dendroctonus* beetles prefer to attack the thick bark of the main trunk and are, therefore, more destructive to mature trees, the engraver beetles usually select thin-bark trees for attack, thereby qualifying as primary enemies of younger trees. Some species are frequently found working in association with *Dendroctonus* beetles, in which case their attack is usually secondary, although some top-killing of trees by these engraver beetles precedes and possibly attracts subsequent infestation by *Dendroctonus* beetles. With the removal of mature forests, some authorities consider it likely that this group of bark beetles will outrank the *Dendroctonus* beetles in destructiveness to the second crop of pines.

The first evidence of attack by *Ips* beetles is yellow or reddish boring dust in bark crevices, or little piles of such dust around the entrance holes or on the ground beneath. Pitch tubes are seldom formed, and the boring dust is usually dry and free from pitch. Within 2 or 3 weeks after a tree has been attacked, the foliage fades and turns from green to yellow, sorrel, and red. Upon removal of the infested bark, the tunnels of the engraver beetles will be found grooving the inner bark surface and, where the phloem is thin, lightly to deeply grooving the sapwood. The egg galleries differ from those of the *Dendroctonus* beetles in that instead of being tightly packed with boring dust they are open runways in which the adult beetles are free to travel the entire length. A second difference is their polygamous social habit of constructing a central nuptial chamber from which fork or radiate several egg galleries. In many trees the pattern of the completed work is sufficiently distinctive to identify the species responsible. However, some species cannot be recognized in this way and can be distinguished only by characters in the adult beetles.

The adults are small, reddish brown to black, often shiny, cylindrical bark beetles ranging from ⅛ to approximately ⅕ inch long. A distinguishing feature is the pronounced concavity on the posterior end, which is margined with three to six pairs of toothlike spines (fig. 65). The small, white, legless larvae differ slightly from *Dendroctonus* larvae in that the body is more tapering and is thicker at the forward end than toward the rear.

Attacks are made by these bark beetles with the coming of warm weather in the spring. An adult male bores through the bark and constructs a small cell or nuptial chamber in the inner bark. Sev-

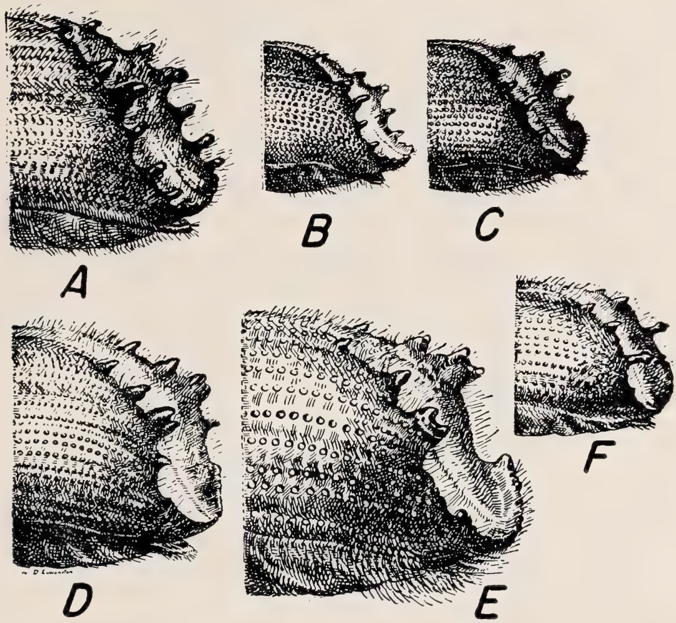

FIGURE 65.—Posterior ends of six species of *Ips*, showing number and arrangement of spines: *A*, *ponderosae* Sw.; *B*, *lecontei* Sw.; *C*, *plastographus* (Lec.); *D*, *knausi* Sw.; *E*, *emarginatus* (Lec.); *F*, *radiatae* (Hopk.). All greatly enlarged. (Drawing by Edmonston.)

eral females then join in the work and each constructs an egg gallery in which eggs are laid in niches along the sides. The larvae, upon hatching, feed in the inner bark and work away from the egg galleries, leaving gradually widening, excrement-packed tunnels behind them. When their feeding is completed oval pupal cells are formed, in which the transformations from larvae to pupae and then to adults take place. The period from the time of attack to the emergence of the new brood is ordinarily 42 to 68 days. From two to five generations of these beetles may develop during the summer, depending on the altitude, latitude, and species, there being considerable overlapping of generations. The winter is usually spent in the adult stage, although occasionally eggs, larvae, and pupae are found. Some species congregate in large groups under the bark of standing trees killed the previous year, and feed to a limited extent on the dry, dead, inner bark. Others emerge and hibernate under the bark of old stumps, among the bark scales, or in crevices and litter at the base of old brood trees.

Engraver beetles have a number of predaceous and parasitic enemies, but apparently these do not affect the numbers of the beetles so much as does the lack of suitable host material. Given a quantity of freshly cut slash or windfalls, a large beetle population is almost certain to be produced but it will not long survive after the supply of this material is exhausted.

Since outbreaks in standing, healthy trees are sporadic and of short duration, the destruction of the broods in these trees, through the application of control methods, seldom contributes a great deal toward reducing the damage. Efforts should be directed toward preventing outbreaks by eliminating all situations favorable to the development of excessive progeny. Thus, slash should be piled and burned before the *Ips* beetles emerge, or should be scattered in the open where the sun will dry it out and make it unsuitable as a breeding medium. If it should be necessary to destroy broods in standing trees, the most economical and effective method is to fell the trees and burn or scorch the infested bark. A large number of species of this genus are recorded from western pines, all very similar in appearance and habits, so only a few of the more common species need be mentioned here.

The western six-spined engraver (*Ips ponderosae* Sw.) is a secondary enemy of ponderosa and digger pines. For the most part it attacks trees that have been felled or those dying from attacks of more primary species of bark beetles. The adults are about ¼ inch long, reddish brown to black, with six spines on each side of the elytral declivity. The gallery pattern consists of two to five egg galleries extending up and down the tree from the central nuptial chamber. Though the pattern is similar to that of *I. oregoni,* the galleries are distinctly wider. This beetle has been recorded from Arizona, California, Montana, South Dakota, and Colorado, and undoubtedly is present in other Western States.

The California five-spined engraver (*Ips confusus* (Lec.)) (fig. 66) is destructive to saplings, poles, young trees up to 30 inches in diameter (breast high), and the tops of mature trees. It commonly attacks ponderosa, sugar, western white, Coulter, digger, and Monterey pines, and, less frequently, other pines in California and southern Oregon west of the Cascade and Sierra Nevada ranges. It breeds readily in slash and felled logs, and the broods developed in such material often cause extensive damage to the young pine growth in the vicinity.

The adults are reddish brown to pitch black, about 3/16 to ⅕ inch long, and have five spines on the margin of each side of the elytral declivity. The egg galleries usually comprise from three to five nearly straight tunnels radiating from a central entrance chamber. The typical form has three galleries in the shape of an inverted Y. The galleries are not packed with boring dust and are usually from 5 to 10 inches long. Attacks are started early in the spring and from two to five generations of beetles may develop during the summer. In the northern part of the range, at an elevation of about 3,000 feet, there are usually two summer generations which develop in fallen logs and a third, or overwintering generation, which develops in standing trees. At lower altitudes and in the southern part of the range there are from three to five summer generations. Most of the beetles overwinter in the adult stage, under the bark of recently killed trees.

Some attempts have been made in California to control outbreaks of this beetle in young pine stands by felling the trees and burning the infested bark during the winter and early spring

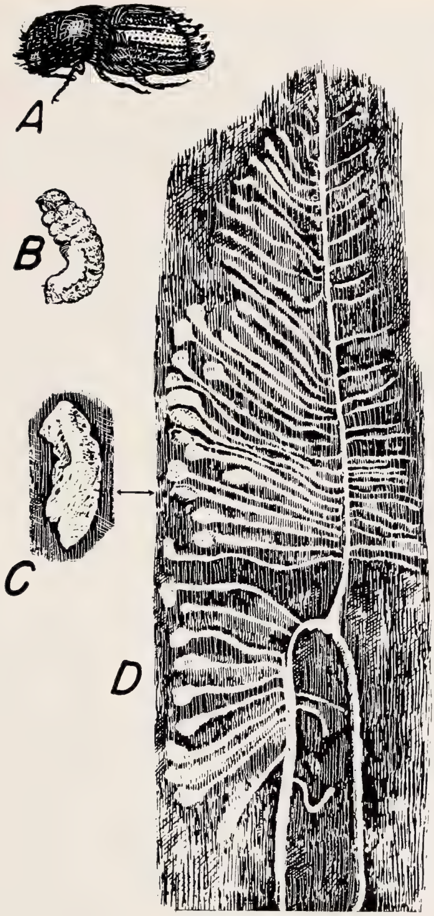

FIGURE 66.—The California five-spined engraver (*Ips confusus*): *A*, Adult, × 5; *B*, larva × 5; *C*, pupa × 5; *D*, typical egg gallery. (Drawing by Edmonston.)

months, much as is done in the control of the western pine beetle. Usually such methods are not warranted, as outbreaks are sporadic and can be avoided if roadway, line, or other slash created late in the winter, in the spring, and early in the summer months is burned or lopped and scattered where it will be fully exposed to the sun. Such precautions are especially important in years showing a marked deficiency in spring precipitation.

The Arizona five-spined engraver (*Ips lecontei* Sw.) (*104*) is the southwestern form of *I. confusus*. It attacks ponderosa and other pines in the southern Rocky Mountain region and at times is exceedingly destructive. Its characteristics and habits are very similar to those of its near relative, and the methods of control

are the same. Some rather extensive operations have been carried on in Arizona to control this beetle.

The Vancouver ips (*Ips vancouveri* Sw.) is also closely allied in character and habits to *I. confusus*, but is slightly larger. The adult beetles are reddish brown to black, about 1/4 inch long, and with five spinelike teeth on the margins at each side of the concave elytral declivity, which is densely clothed with long, slender hairs. These beetles usually attack decadent or weakened western white pine, lodgepole pine, and Sitka spruce throughout the Northwest, but under favorable conditions will attack apparently healthy trees. The gallery pattern is of a radiating, longitudinal type with three to five short egg galleries extending up and down the tree from the nuptial chamber. There are apparently two but possibly three generations a year.

The Cloudcroft ips (*Ips cloudcrofti* Sw.) is a secondary enemy of pines in the high mountains of New Mexico. It is a slender species with five pairs of spines on the elytral declivity and is closely related to *I. confusus* in character and habits.

The emarginate ips (*I. emarginatus* Lec.) is most frequently found associated with the mountain pine beetle in its attacks on ponderosa, lodgepole, and western white pines, and with the Jeffrey pine beetle in Jeffrey pine, but occasionally kills trees by itself. This is the largest western species of *Ips*. Its range extends through California, north to southern British Columbia, and east through Idaho to western Montana. The adults are dark-brown, cylindrical bark beetles about 1/4 inch long, with three prominent spines along each side of the elytral declivity, and a fourth nearly obsolete spine. Their work is characterized by the long, straight, nearly parallel egg galleries from 2 to 4 feet long, which run up and down the tree and connect at different points (fig. 67). Owing to the similarity in length and width of the egg galleries, its work is often confused with that of the mountain pine beetle, with which it is so often associated. However, the presence of a nuptial chamber and the absence of packed boring dust in the *Ips* galleries will distinguish their work. In the northern part of its range this species has two complete generations a year, but in the southern part there are a number of summer generations with considerable overlapping of broods. Control work has included this species when in association with more aggressive bark beetles, but no separate control has ever been required.

Knaus' ips (*Ips knausi* Sw.) attacks lodgepole, ponderosa, and Arizona pines through the pine belt of Arizona, New Mexico, and Colorado. It is usually a secondary enemy. In its habits, character of work, and appearance it closely resembles its near relative, *I. emarginatus*, and may be considered the southern Rocky Mountain form of this beetle.

The smaller western pine engraver (*Ips latidens* (Lec.)) usually confines its attacks to the tops and limbs of dying or weakened pines. Under favorable conditions it has demonstrated its ability to kill trees, particularly those weakened by mistletoe or drought, and in some instances even healthy trees of small diameter. It is a primary killer of digger pine and is common in the

FIGURE 67.—Galleries and pupal cells of the emarginate ips (*I. emarginatus*) on the inner bark surface of ponderosa pine.

tops of lodgepole pine killed by *Dendroctonus* beetles. During severe epidemics of the mountain pine beetle in lodgepole pine it often develops in such numbers as to attack and destroy many small trees.

The adults are the smallest of the western species and are about ⅛ inch long. They are distinguished by having three small, spine-like teeth along the margin of the elytral declivity, which is nearly vertical. Its typical work consists of from two to five rather short, sometimes curved, egg galleries radiating from the central nuptial chamber. It is distributed throughout most of the Western States, where it attacks ponderosa, sugar, digger, lodgepole, Jeffrey, Coulter, western white, and probably other pines. *I. guildi*

Blkm. is a closely related form which attacks lodgepole and other pines in Colorado and the central Rocky Mountain region.

The sawtooth pine engraver (*Ips integer* Eichh.) is distributed throughout the Western States, but is most common in the Rocky Mountain region. It generally breeds in weakened or felled ponderosa, lodgepole, western white, and limber pines, and western larch, but under favorable conditions it may become primary. The stout, brownish-black adults are about 1/5 inch long and have four spinelike teeth along the margin on each side of the concave elytral declivity. This species constructs three or four straight longitudinal egg galleries that fork from the common entrance or nuptial chamber. The egg niches are so thickly and evenly spaced along the sides of the egg galleries as to give these a sawtoothed appearance—a distinctive feature of this species' work.

The California pine engraver (*Ips plastographus* Lec.) is a species, closely related to *I. integer,* which prefers to attack the trunks and branches of felled Monterey, Bishop, and lodgepole pines, but at times also attacks weakened or dying standing trees. It is not often primary in its attacks, but is usually associated with the Monterey pine engraver and the red turpentine beetle in the killing of living trees or trees injured by fire or other causes. It is found through the range of its host trees in the coastal belt of middle California and in the Sierras. The adults are about 1/5 inch long, with four pairs of spines on the posterior margin of the wing covers. The work pattern is very similar to that of *I. confusus,* the typical form having three egg galleries from 5 to 15 inches long, issuing from each entrance chamber. There are from three to five generations annually, depending on the locality and season.

The Oregon pine engraver (*Ips oregoni* (Eichh.)) is distributed throughout the interior forests of the Western States, where it may be found breeding in almost any species of pine. It is most commonly found attacking and killing interior ponderosa, Jeffrey, and lodgepole pines (fig. 68). Large numbers develop in such host material as windfalls, freshly cut logs, pieces of slash over 2 inches in diameter, and in the tops and limbs of trees killed by *Dendroctonus* beetles. When conditions are favorable and suitable host material is plentiful, they frequently develop in such numbers as to become aggressive in their attacks on healthy living trees. However, such outbreaks are usually of short duration and seldom last more than one season. The most frequent damage is in the killing of young replacement trees from 2 to 8 inches in diameter and the top-killing of older trees.

The adults are reddish brown to nearly black, about 1/6 inch long, and have four small teeth along the margins on each side of the elytral declivity. A typical sample of their work shows three or four egg galleries forking from a central nuptial chamber and running more or less longitudinally with the grain of the wood for a distance of 5 to 10 inches. There may be anywhere from one to seven females to each male, with as many egg galleries radiating from the one nuptial chamber. There are from two to four generations of this species a year, depending on the locality and the

FIGURE 68.—*A*, Typical galleries of the Oregon pine engraver score the sapwood; *B*, adult, × 4.

length of season. The parent adults often emerge and make a second and even a third attack that results in a confusing overlapping of broods. Preventing these beetles from becoming too numerous through timely slash disposal will do more to prevent damage than the application of control measures after damage has occurred.

The Monterey pine engraver (*Ips radiatae* Hopk.) attacks living, injured, dying, and recently felled Monterey, Bishop, knobcone, lodgepole, and whitebark pines from central California northward to British Columbia and eastward to Idaho and Wyoming. It is usually a secondary enemy and associated with other bark beetles in its attack, but at times may become primary, espe-

cially in plantations of Monterey pine. The adult beetles are about 1/5 inch in length, dark brown and shining, with parallel sides and one very prominent spine and two smaller ones on the end of each wing cover. The egg galleries are curved or S-shaped, with three or four larval mines issuing from each egg pocket (fig. 69). The

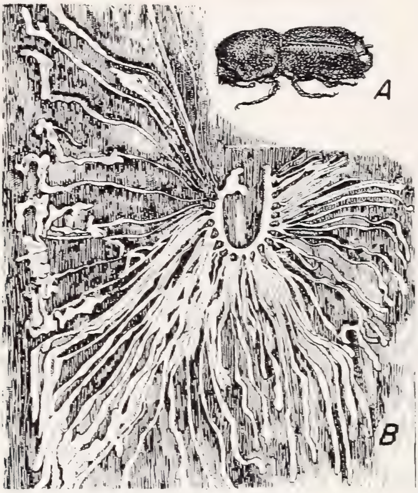

FIGURE 69.—Monterey pine engraver (*Ips radiatae*): *A*, Adult × 4; B, pattern of work on sapwood.

rapidity of development and the number of generations varies with different seasons and localities. Usually there are one or two summer generations and an overwintering generation. The beetles overwinter beneath the bark of trees killed during the previous summer, mostly as adults, but also as larvae and pupae. Some extensive control operations have been undertaken in California to suppress outbreaks of this beetle that developed from roadway slashings.

The small bark beetles belonging to the genus *Pityogenes* are sometimes referred to as wood engravers. They usually are of secondary importance and attack the tops, limbs, and twigs, of weakened, dying, and newly felled trees; but, like other secondary species, under favorable conditions they may develop in sufficiently large numbers to attack and kill small trees growing in the vicinity of their breeding place. The adults are small, slender, dark-brown beetles about 1/8 inch long, with two or three small, spinelike teeth along the margin of a slightly concave elytral declivity. The teeth are much larger in the males, with the first pair often developed into prominently curved spines. The females have a deep impression on the front of the head. They are polygamous and excavate more or less circular, nuptial chambers under the bark.

Pityogenes carinulatus (Lec.) is a stout, reddish-brown species

which breeds in ponderosa, lodgepole, white-bark, Jeffrey, and probably other pines and is distributed over nearly all the Western States. The females have three small, spinelike teeth along each margin of the elytral declivity, whereas the males have only two declivital teeth on each side, the first pair strongly developed into prominently curved spines. Their gallery pattern consists of 8 to 10 or more rather slender egg galleries from 1 to 2 inches long, radiating from a circular entrance chamber.

Pityogenes knechteli Sw. is a slender species similar to the above, commonly found associated with *Ips* and *Dendroctonus* beetles under the thin bark of lodgepole and other pines in the Western States and in British Columbia, and is sometimes responsible for the destruction of small patches of lodgepole pine reproduction. The work consists of three to five egg galleries 1½ to 3 inches long, radiating from the central nuptial chamber.

Pityogenes fossifrons (Lec.) is a brownish-black species occasionally found working in the tops and limbs of weakened or dying western white, whitebark, limber, lodgepole, and other pines from California northward to British Columbia and eastward to Idaho. Its attacks are seldom primary, although it sometimes attacks western white pine reproduction. The adults have three very small spines along each margin of the elytral declivity, somewhat larger in the males. Their gallery pattern consists of four to six egg tunnels 1 to 1½ inches long, radiating from the entrance or nuptial chamber (fig. 70).

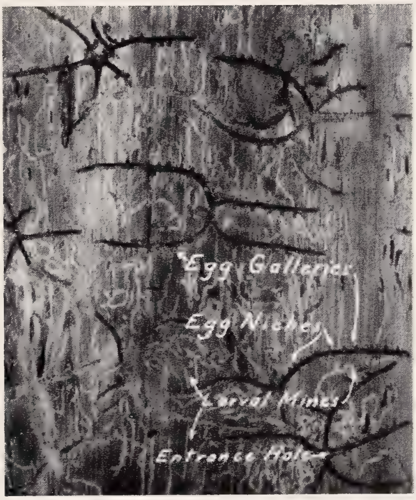

FIGURE 70.—Typical galleries and egg niches of *Pityogenes fossifrons*.

Several other species of small engraver beetles may be encountered under the bark of pines. *Orthotomicus ornatus* Sw. is a small species about ⅛ inch long, closely resembling a small *Ips*. The elytral declivity is slightly concave, with three pairs of small

teeth, the second and third pairs of teeth being larger on the males. Their work is similar to that of *Pityogenes,* and they are frequently found under the thick bark of ponderosa, Jeffrey, and lodgepole pines in small mines, intermingling their work with that of the pine beetles. Another species, *O. vicinus* (Lec.) closely related to the eastern *O. caelatus* (Eichh.), infests lodgepole and western white pines, Engelmann spruce, and western larch in Colorado and the Northwestern States and Canada.

Some species of the genus *Pityophthorus* are occasionally found under the thick bark of dying pines, and may be responsible for the death of weakened trees (p. 37).

Other Secondary Bark Beetles

A number of secondary bark beetles belonging to the genera *Hylastes, Hylurgops,* and *Pseudohylesinus* are commonly found in the inner bark of dying pine, spruce, fir, and hemlock, and are frequently mistaken for destructive species. Actually, they seldom or never cause the death of healthy trees by their unaided efforts.

Species of the genus *Hylurgops* are often referred to as sour-sap beetles, since they are most commonly found in the wet fermenting inner bark at the base of trunks or in the main roots of dying or dead trees, or in freshly cut stumps. *H. subcostulatus* (Mann.) a small russet-brown, scaly beetle about $\frac{3}{16}$ inch long, excavates a short, slightly curved, longitudinal egg gallery in the moist inner bark of ponderosa, sugar, Jeffrey, shore, lodgepole, and western white pines throughout the West. *H. rugipennis* (Mann.) is a narrow reddish beetle, slightly longer than the above, which works in pines, Engelmann spruce, and western hemlock in the Pacific coast and northern Rocky Mountain regions. *H. porosus* (Lec.) is less common than the two above-named species, but has been recorded from nearly all pines throughout the West. *H. lecontei* Sw. is also widely distributed and has been recorded from lodgepole, Monterey, and ponderosa pines, and white fir in western United States.

Species of *Hylastes* are small, elongate, dull-brown to black beetles, which are also found under the bark and in roots of dying or dead conifers and breeding in slash. Often the adults fly in great numbers and are picked up around sawmills and lumber piles. Reported "swarms of pine beetles" often are one or more of these species, for the more destructive pine beetles are not often taken in flight. Occasionally where large swarms of these beetles emerge they will feed on the tender bark of young trees, and small trees an inch or more in diameter may be killed by beetles girdling the bark at or below the root collar. These beetles may also be found breeding in the roots of suppressed or weakened seedlings.

Several western species have been found doing this type of damage. *Hylastes gracilis* Lec., a dark reddish-brown beetle $\frac{3}{16}$ inch long, is commonly taken in flight. It is reported breeding in ponderosa, sugar, and pinyon pines and white fir throughout the West.

H. longus Lec. is a dark reddish-brown species about 3/16 inch long which breeds in ponderosa pine in Colorado and New Mexico. *H. macer* Lec. is a pitch-black species nearly 1/4 inch long, which breeds in ponderosa, sugar, Jeffrey, and lodgepole pines and Engelmann spruce throughout the West. *H. minutus* Blkm. is a small (3/32 inch long) dark reddish-brown to black species found breeding in ponderosa pine and Douglas-fir in California, Oregon, and Nevada. *H. nigrinus* (Mann.) is a dark-brown to pitchy-black species slightly over 3/16 inch long, commonly found along the Pacific slope and east to Idaho, breeding in Douglas-fir, true fir, spruce, and western hemlock, and in shore, Monterey, and western white pines. *H. ruber* Sw. is a bright, shiny, reddish-brown species nearly 1/4 inch long, which is commonly taken in flight and is reported from Douglas-fir in the Pacific Coast States, Idaho, and Montana.

Pseudohylesinus sericeus (Mann.) a small, stout beetle 1/8 inch long, attacks weakened or dying shore pine and Monterey pine along the coast of California and north to Alaska. Its egg tunnels are short and longitudinal.

FIR BARK BEETLES

The true firs and Douglas-fir, as well as pines, have their full share of bark-beetle enemies (*13, 30*). In general the destructive species are different from those attacking pines, though many of the secondary species may be the same. Douglas-fir growing under favorable conditions in the commercial stands of western Oregon and Washington seems to be resistant to bark-beetle attack, although sporadic group killing in thrifty stands sometimes occurs, especially after beetles have developed in fire-killed timber (*96*). At times this tree suffers from bark beetles, even in this region of favorable growth. In the eastern portion of the Douglas-fir range, where growth conditions are less favorable and the timber is of inferior quality, bark-beetle outbreaks of disastrous proportions are not an uncommon occurrence. The Douglas-fir beetle causes most of the damage. Small Douglas-firs are frequently killed by the fir engraver beetles, particularly in situations where large numbers of these small beetles have developed in windfalls or slash. The engravers usually responsible for this type of damage are *Scolytus unispinosus* or *Pseudohylesinus nebulosus*.

The true firs are very susceptible to bark-beetle damage, and in certain years outbreaks sweep through fir stands and kill a high percentage of the trees. In such years it is not uncommon to see entire hillsides turn red with the discolored foliage of dying trees. Since true firs in the West have not been of great commercial value until recently, no estimates have been made as to the extent of such damage.

In addition to aggressive tree-killing fir bark beetles, there are also a large number of secondary species that breed in dying or dead trees, slash, and broken tops. These, under exceptionally favorable circumstances, may become destructive to living trees.

The Douglas-fir beetle (*Dendroctonus pseudotsugae* (Hopk.) is the most important bark-beetle enemy of Douglas-fir throughout

its range in the Western States. It also attacks western larch. Normally it confines its attacks to felled, injured, or weakened trees and is not of great importance. At times, however, it becomes aggressive and kills apparently healthy, mature trees, singly and in groups, over extensive areas. Some serious epidemics have occurred in the Rocky Mountain region, particularly where trees were weakened by drought, fires, or defoliations, or where trees close to logging operations have been attacked by broods developed in slash. In the commercial Douglas-fir region of Oregon and Washington outbreaks are of less frequent occurrence, although the killing of groups of mature trees in second-growth stands is not uncommon.

Reddish or yellow boring dust caught in bark crevices or around the base of trees gives the first evidence of attack by the Douglas-fir beetles, as no pitch tubes are formed. The adults are reddish to dark brown, often black, beetles about 1/5 inch long and very similar to other *Dendroctonus* beetles (p. 131) except for their reddish color and their covering of conspicuous long hairs. These beetles work in pairs and construct egg galleries which are mostly in the inner bark, though they also slightly etch the sapwood. Typical galleries are perpendicular, usually straight or slightly sinuous (fig. 71) and average about a foot in length, though they may range from 6 to 30 inches. The eggs are laid in masses of 10 to 36 in grooves, at alternate intervals along the sides of the gallery. The larval mines diverge from the egg groups and are extended through the inner bark close to the wood. They expand as the larvae grow, so the completed work from each group of eggs is somewhat fan-shaped. The pupal cells, which are constructed at the ends of the larval mines, may be exposed when the bark is removed from the tree, or they may be concealed in it, depending on the thickness of the bark. In these cells the transformation from larvae to pupae and then to new adults takes place. The new adults bore away the intervening bark between pupal cells and congregate, sometimes for rather long periods, beneath the bark. Finally they bore through the bark to the surface, emerge, and fly to make their attack on other trees.

Ordinarily the Douglas-fir beetle passes the winter in the adult stage, although small to mature larvae also may be found. The overwintering adults emerge rather early in the spring, but the delayed broods mature and emerge at any time throughout the summer months. It is also possible that some of the young overwintering larvae do not have time to complete their development before cold weather overtakes them in the fall, and consequently they are obliged to spend another winter in the host tree. One generation of beetles a year is probably the normal rate of development, but there is considerable overlapping and retardation of broods, somewhat obscuring the demarcation between generations.

The usual method of direct control is to fell the tree and cut the infested bole into logs, which are then decked and burned. As a large percentage of these insects overwinter as adults and emerge early in spring, fall control is the most effective.

FIGURE 71.—The Douglas-fir beetle (*Dendroctonus pseudotsugae*): *A*, Galleries on inner bark surface (natural size); *B*, larva; *C*, adult, × 4.

A number of small bark beetles, belonging to *Scolytus*, *Pseudohylesinus*, and related genera, commonly work under the bark and score the sapwood of dying, broken, or felled firs, but at times may attack and kill small trees. Beetles in this group are called fir engraver beetles.

Members of the genus *Scolytus*, are small, shiny, dark, or nearly black bark beetles, which are easily recognized by the concave appearance of the posterior ventral surface of the abdomen. The adults feed for some time by making feeding pits in the twigs and later attack in pairs and construct short egg galleries, usually from a central entrance chamber. The larvae work out at right angles from the egg gallery and bore through the phloem and

inner bark, usually deeply scoring the sapwood. Some members of the genus are exceedingly destructive to true firs. Others work in Douglas-fir, hemlock, spruce, or even in broadleaved trees.

The Douglas-fir engraver (*Scolytus unispinosus* Lec.) is commonly found attacking weakened, injured, dying, or recently killed Douglas-fir in the Pacific Coast States and British Columbia. Sometimes it is a primary enemy of young Douglas-firs. The adults are small, black, cylindrical, shining bark beetles about $\frac{1}{8}$ inch in length, with a long spine projecting from the middle of the nearly perpendicular face of the ventral declivity. The typical egg gallery follows the grain of the wood and may range in length from $1\frac{1}{4}$ to 3 inches. A short entrance tunnel leads into the main gallery, at an angle of 45°, and a small nuptial chamber is constructed at the juncture (fig. 72). The larvae work out at more or

FIGURE 72.—Work of the Douglas-fir engraver (*Scolytus unispinosus*).

less of a right angle from the egg gallery, and then work up or down the tree so that the mines will not cross one another. The winter is spent in the egg and young larval stages. Emergence of adults takes place late in April, in May, June, and July. There appear to be two generations annually. *S. fiskei* Blkm. is a closely related species found attacking Douglas-fir in New Mexico and Colorado.

The fir engraver (*Scolytus ventralis* Lec.) (*148*) is found at-

tacking the true firs in all the Western States and in British Columbia, and at times has been exceedingly destructive to white fir stands in California and Oregon. The adult is a short, shiny black bark beetle about 1/8 inch in length, without a prominent spine on the ventral declivity. The egg galleries are excavated in the inner bark and cut transversely across the grain of the wood, which they score rather deeply for a distance of 2 to 6 inches on both sides of a central entrance chamber.

Eggs are laid in niches along both sides of these galleries and the larvae, on hatching, work up and down the bole (fig. 73), ex-

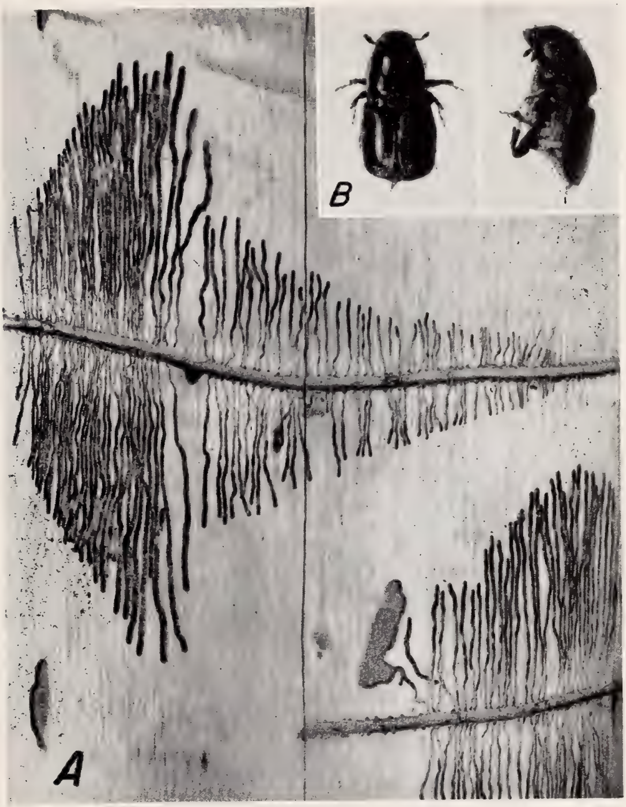

FIGURE 73.—The fir engraver (*Scolytus ventralis*): *A*, Egg galleries and larval mines; *B*, adults, × 5.

tending their individual larval mines for a distance of 5 to 7 inches. A brown stain of the cambium caused by a fungus is always found in the area in which the larvae feed. Pupation occurs in the inner bark at the end of the larval mines, and the new adults bore directly to the surface of the bark when ready to emerge. Frequently green trees are attacked and new broods develop and emerge without destroying enough of the cambium to kill the tree.

The patch of dead cambium heals over and leaves only a brown pitch pocket in the wood to mark the place of injury. Some wood sections have shown as many as seven such attacks during the life of the tree, which indicates that a certain amount of activity by this beetle is constantly going on in the forest. Trees are attacked during the summer months, and the eggs hatch and larvae develop before winter. The winter is usually passed in the larval stage, and the new broods emerge the following year. These beetles normally have but one generation annually. Because of the sporadic character of outbreaks and the possible presence of healthy broods in living trees no methods of control appear practical.

Other species of *Scolytus* which may be found in western firs include *S. subscaber* Lec., a large species which makes E-shaped galleries in the limbs of white and red fir (fig. 74); *S. praeceps*

FIGURE 74.—*Scolytus subscaber*: *A*, E-shaped galleries on limbs of white fir; *B*, adults, × 4.

Lec., a small species about ⅛ inch long, which attacks the limbs and small tops of white fir and other firs in Oregon, California, Arizona, and New Mexico; and *S. monticolae* (Sw.), about ⅛ inch long, which is recorded by Swaine as attacking western white pine and Douglas-fir in British Columbia, Washington, Oregon, Idaho, Montana, and Wyoming. *S. reflexus* Blkm. attacks Douglas-fir in Arizona and probably in other Southwestern States.

Some of the species of the genus *Pseudohylesinus* are also frequently found in various firs. They usually are secondary in habit but at times some species are destructive. Their work is very similar to that of *Scolytus* in that the typical egg gallery consists of two short, straight branches from a central entrance tunnel. The work usually can be distinguished from *Scolytus* in that no enlarged nuptial chamber, scoring the sapwood or visible on the inner surface of the bark, is constructed, as is the case with *Scolytus*. Another distinguishing feature between these two genera is that the wing covers of *Pseudohylesinus* are densely covered with scales, and therefore are dull in appearance instead of shiny. Moreover, the beetles are nearly oval in outline and do not have the concavity at the rear of the abdomen which is such a distinctive feature of *Scolytus*.

The Douglas-fir hylesinus (*Pseudohylesinus nebulosus* Lec.) is frequently found attacking recently felled or injured small Douglas-firs through the range of this tree in the West. It seems to prefer the thin bark of saplings, or poles, or limbs of larger trees, and frequently kills trees of small diameter. The adults are small, grayish to yellowish-brown, variegated bark beetles about 1/8 inch long. Usually a short longitudinal egg gallery is constructed in the cambium layer, often with two branches, originating from a central entrance tunnel, one up and one down the trunk, parallel with the grain of the wood (fig. 75). Their work is very similar to and easily confused with that of *Scolytus unispinosus*, but is

FIGURE 75.—Adults and galleries of the Douglas-fir hylesinus (*Pseudohylesinus nebulosus*).

distinctive in that no well-defined nuptial chamber is visible on the inner surface of the bark. The larval mines diverge from the egg gallery and end in pupal cells in the inner bark. There appear to be two generations a year. *P. serratus Bruck* is a related species which attacks bigcone spruce in southern California.

The grand fir bark beetle (*Pseudohylesinus grandis* Sw.) attacks the trunks or limbs of weakened or dying Douglas-fir, and grand, white, Pacific silver, alpine, and red firs. It usually is of secondary importance. The adult beetles are about 1/8 inch long, rather stout, elongate-oval, densely covered with brown and gray scales which sometimes form V-shaped markings on the wing covers. They work in pairs and each pair constructs a short, transverse egg gallery for 2 or 3 inches, sometimes on only one side but more frequently on both sides of the entrance tunnel. The work is very similar to that of *Scolytus ventralis,* except that the egg gallery is narrower, not so uniformly straight, and without the well-defined entrance chamber. There are one or two generations a year, depending on the locality. It is distributed from California to Alaska and eastward into Montana.

The noble fir bark beetle (*Pseudohylesinus nobilis* Sw.) is very similar to the above and is found breeding in dying noble fir and Pacific silver fir in Oregon and Washington.

The fir root bark beetle (*Pseudohylesinus granulatus* (Lec.)) is a larger, very dark reddish to black species about 1/5 inch long, with very rough elytra and prominent striae. It is a secondary

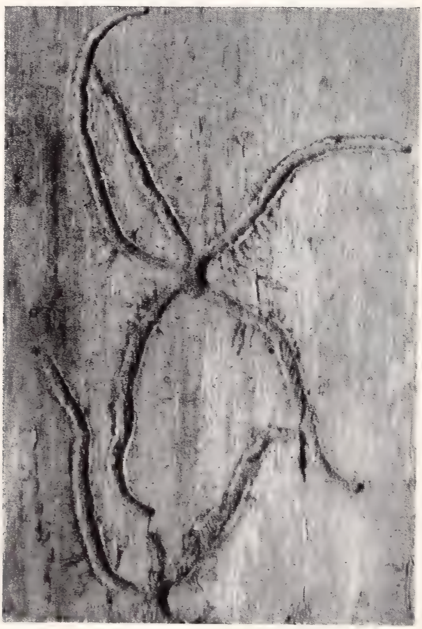

FIGURE 76.—Galleries of the western balsam bark beetle (*Dryocoetes confusus*).

enemy of white, grand, red, Pacific silver, and possibly other firs from California to British Columbia and eastward into Montana. It makes a short horizontal egg gallery under the bark of dead or dying firs, particularly at the extreme base or in the main roots.

Some of the species of *Dryocoetes* are found working under the bark of firs. While they are usually secondary enemies, they at times attack and kill apparently healthy trees.

The western balsam bark beetle *Dryocoetes confusus* Sw. (*108*) is probably the most destructive member of the group and often attacks alpine fir and sometimes other species of fir, spruce, and pine. The adults are rather short, reddish-brown bark beetles about $\frac{1}{8}$ inch long. They construct a small, circular nuptial chamber under or in the bark, with several radiating egg galleries which may score the sapwood (fig. 76). There is probably only one generation a year. The species is distributed throughout the Northwestern States from British Columbia southward in Oregon and eastward to Colorado.

Dryocoetes pseudotsugae Sw. is a secondary enemy of Douglas-fir. The adults are reddish brown and are about $\frac{3}{16}$ inch long. They construct short, irregular galleries in the inner bark of windthrown and dying trees throughout California and northward to British Columbia. The young adults gather in galleries in the outer or inner bark, not in the cambium, to pass the winter. Adults emerge early in the spring. Trees attacked in the spring produce mature beetles by August. There is one generation and probably a partial second each year.

SPRUCE BARK BEETLES

Spruce trees are attacked by a large number of bark beetles, most of which are secondary enemies, breeding only in dying, felled, or weakened trees. A few species, however, such as the Engelmann spruce beetle and the Sitka spruce beetle, become exceedingly destructive at times. Young trees are sometimes killed by species of *Ips, Pseudohylesinus,* and *Dryocoetes,* and by other small engraver beetles.

The Engelmann spruce beetle (*Dendroctonus engelmanni* Hopk.) at relatively long intervals causes widespread destruction of Engelmann spruce in the Rocky Mountain region. It will also attack other species of spruce, and sometimes lodgepole pine, within its range, which covers Oregon, Washington, Idaho, Montana, Wyoming, the Black Hills of South Dakota, Utah, Colorado, Arizona, and New Mexico. In endemic infestations large, overmature, or mechanically weakened trees are preferred, with attacks seldom extending below 6 feet above the ground. Distinct preference is also shown for windfalls or logs. Blowdown areas are a primary source of epidemic outbreaks. During epidemics trees of all ages and diameters, except reproduction, are attacked, preference being shown for trees of larger diameter. The bole length of infestations varies, but averages from 18 to 20 feet in the lower bole portion, from 2 to 3 feet above ground level.

The adult beetles are about $\frac{1}{4}$ inch long, dark reddish-brown to black, the body sparsely clothed with long hairs. They excavate a

short, nearly straight, longitudinal egg gallery in the inner bark, slightly scoring the sapwood. The gallery is wider than the beetles and is packed with boring dust through which the adults keep a passageway open. Eggs are laid in masses in elongate cavities which alternate from side to side of the gallery. At first the larvae bore out en masse, transversely from the egg gallery, but later make separate mines. The pupal cells are usually constructed in the inner bark, being exposed when the bark is removed, but are sometimes deeper in the bark and quite concealed in thick-bark trees.

Two years are required to complete a generation, from attack to attack, in the main body of Engelmann spruce stands. At high elevations 3 years may be required, and in the lower elevations one generation may occur each year. The principal flight, attack, and egg laying takes place when hibernated adults emerge after the snow disappears late in June and in July. Eggs hatch and larvae develop during the summer. The progeny pass the winter as half to nearly full-grown larvae, and complete development to adults by the following August. The new adults emerge and migrate to the basal trunk and root collar of the host tree from August to October; there they bore beneath the bark and hibernate until the ensuing June and July. Overwintering stages consist primarily of hibernating adults of the previous seasonal attacks and half- to three-fourths-grown larvae of the current seasonal attacks.

The thin bark of Engelmann spruce and the characteristic lower bole infestations offer good possibilities of control with insecticides dissolved in fuel oil. One part of orthodichlorobenzene in six parts of fuel oil has been most commonly used. Benzene hexachloride at 0.46 percent of the gamma isomer was 96 percent effective when sprayed on standing trees. Adults are slightly more susceptible to the lethal effects of these sprays than larvae. The best time for control is in September and October, when all overwintering stages may be killed. Outbreaks are difficult to detect, because the foliage does not fade until 1 year after attack, and it turns pale green only before dropping. There are no pitch tubes. First-year attacks can be detected only by the presence of brown boring dust around the base of trees. Woodpecker work also helps to identify the trees after about October 1, when the larvae are large.

The Alaska spruce beetle (*Dendroctonus borealis* Hopk.) attacks white and Engelmann spruce in Alaska and northwestern Canada. In appearance and habits it is very similar to the Engelmann spruce beetle, to which it is closely related.

The Sitka spruce beetle (*Dendroctonus obesus* (Mann.)) is usually considered a secondary enemy of Sitka spruce, but at times it becomes destructive and kills a considerable volume of spruce along the coast of Oregon, Washington, British Columbia, and Alaska. The most recent outbreak on Kosciusko Island, in Alaska, killed an estimated 35½ million board feet of Sitka spruce during the few years prior to 1946. The adults are black and similar to the Engelmann spruce beetle in size and shape. The pattern of their work is also much the same, except that the larval mines appear to be even more generally connected toward the egg gal-

lery. Beetles fly and make new attacks mostly during May and June, and new broods complete their development to new adults before winter. There is one generation a year, which passes the winter mostly in the adult stage, and a partial second generation, which overwinters as larvae. No control work has been attempted for this bark beetle.

Many species of small engraver beetles, which breed in the dying bark of felled or weakened trees, sometimes become so plentiful as to bcome dangerous to small spruce trees and the tops of older trees. These belong to the same genera that are met with in pines and firs.

The Sitka spruce engraver (*Ips concinnus* Mann.) attacks the bark of living, dying, or felled Sitka spruce along the coast of Oregon and northward to Alaska. No reports have been received of its having done more than nominal damage. The adults are about ⅛ inch long, with three teeth, one very prominent and two smaller, on each side of the concave elytral declivity. They excavate an irregular central nuptial chamber, with three or four short curved or S-shaped galleries radiating therefrom. Four eggs are laid in each egg pocket and the four larval mines issuing from each pocket are a characteristic feature of its work. (See p. 144 for a general discussion of the work and habits of the *Ips* beetles.)

Other species of *Ips* which attack spruce include the following:

Species of *Ips*	*Host and distribution*
perturbatus (Eichh.)	White spruce. Northern Canada and Alaska.
interpunctus (Eichh.)	White spruce and Engelmann spruce. Alaska, Yukon, and British Columbia.
interruptus (Mann.)	Sitka spruce, white spruce. Oregon to Alaska and eastward.
dubius Sw.	Engelmann spruce. British Columbia and Canadian Rockies.
tridens (Mann.)	Engelmann, Sitka, and probably white spruces. Canadian Rockies, British Columbia, and Washington.
engelmanni Sw.	Engelmann and white spruces in same region.
pilifrons Sw.	Engelmann spruce. Idaho and Colorado.

The Sitka spruce hylesinus (*Pseudohylesinus sitchensis* Sw.) is a small, densely scaly, suboval bark beetle which is found attacking limbs and twigs of felled or dying Sitka spruce in British Columbia, Washington, Oregon, and California. It makes a short, 1-inch, slightly curved, longitudinal egg gallery with a shoe-shaped entrance. The larvae work laterally and pupation occurs in the bark or slightly submerged in the sapwood.

Dryocoetes affaber Mann. attacks the tops of felled and dying Sitka, Engelmann, and other spruces, and Douglas-fir from Alaska southward into the Northwestern States. The adults, which are less than ⅛ inch in length, construct irregular, short egg galleries.

Dryocoetes confusus Sw. (p. 163) may also be found attacking and sometimes killing Engelmann and other spruces.

Scolytus piceae (Sw.) attacks white spruce in eastern Canada, but extends westward into Alberta, South Dakota, North Dakota, Montana, Wyoming, and Colorado, where it may be found on En-

gelmann spruce. It makes a short longitudinal egg gallery with one branch above and one below a central nuptial chamber.

Several secondary species of very small bark beetles may be found breeding abundantly in dying spruce along with the more primary tree-killing species, usually with their egg tunnels starting from those of *Ips* or *Dendroctonus*. *Crypturgus borealis* Sw. is a small brownish beetle about 1/16 inch long that breeds abundantly in spruces, larch, some firs, and western white pine in the Rocky Mountain region and on the Pacific slope. *Dolurgus pumilus* (Mann.) is about the same size and does similar work in spruce and western white pine along the Pacific slope from Alaska to southern California. *Scierus annectens* Lec., a small reddish-brown beetle about 1/8 inch long, breeds in white and Engelmann spruces, lodgepole pine, and probably in Sitka spruce in western Canada, the Northwest, and the Rocky Mountain States.

The four-eyed spruce bark beetle (*Polygraphus rufipennis* (Kby.)) is a common secondary species which breeds in the dead and dying bark of trees and stumps of spruce throughout the Northern States. The adult beetles are stout, cylindrical, black, and about 1/8 inch long. They construct a central nuptial chamber in the inner bark, from which radiate three to five short, curved egg galleries. There appears to be only one annual generation. They breed in all western spruces and also have been recorded from lodgepole pine, limber pine, larch, and Douglas-fir.

HEMLOCK BARK BEETLES

While hemlocks have a number of bark-beetle enemies, these are mostly of secondary importance, and seldom are any large number of trees killed.

Western hemlock is sometimes attacked and killed by the Douglas-fir beetle (p. 155) when associated with Douglas-fir. At times weakened trees are attacked by species of *Scolytus* and *Pseudohylesinus*.

Mountain hemlock, when in mixture with lodgepole pine, is sometimes killed by the mountain pine beetle (p. 135), but is most frequently attacked by a species of *Scolytus*.

The hemlock engraver (*Scolytus tsugae* (Sw.)) is a small, dark, shiny bark beetle about 1/8 inch long, with the wing covers projecting over the concave abdomen. It constructs a short, straight egg tunnel across the grain, from one or both sides of a small entrance chamber. Mountain hemlock, western hemlock, and Douglas-fir are attacked. At times the species is very destructive. It is distributed from British Columbia southward into California and eastward into Idaho.

The hemlock hylesinus (*Pseudohylesinus tsugae* Sw.) is a stout, oval bark beetle about 1/8 inch long, reddish brown, and sparsely clothed with scales and short, stout hairs. It breeds prolifically in felled and dying western hemlock and also is known to attack Pacific silver fir. It sometimes kills apparently healthy trees. It is reported from British Columbia, Washington, Oregon, and California.

BARK BEETLES AFFECTING LARCH

Western larch is quite resistant to insect enemies, but it sometimes is killed by species of bark beetles that work in various other coniferous trees. Probably its most serious bark-beetle enemy is the Douglas-fir beetle (p. 155). Dying and felled trees may be attacked by *Ips integer* or other small engraver beetles.

The larch engraver (*Scolytus laricis* Blkm.), which is very similar to *S. unispinosus* in appearance and habits (p. 158), has recently been described by Blackman (*14*) from specimens found breeding in this tree.

CEDAR BARK BEETLES

All the closely related trees belonging to the families Taxodiaceae and Cupressaceae, such as the various cypresses, California incense cedar, Port Orford cedar, Alaska yellow cedar, western redcedar, redwood, and the various junipers, are attacked by diverse species of one genus of bark beetles, *Phloeosinus*. Not only is this genus practically confined to this group of trees (one species has been doubtfully recorded from pine), but as these trees have almost no other bark-beetle enemies, any species found working in the inner bark of cedarlike trees is almost certain to be a species of *Phloeosinus*. As a general rule these small oval beetles are not aggressive in their attack and are found working under the bark of trunks, tops, and limbs of weakened, dying, or felled trees, or of broken branches. Occasionally, however, they become sufficiently numerous and aggressive to attack and kill apparently healthy trees. Usually the greatest injury by these bark beetles is due to their habit, as newly emerged adults, of feeding on the twigs of healthy trees, causing them to break or die. This habit is similar to that of most species of *Scolytus*. In constructing their brood burrows the beetles work in pairs, and, while there is some variation in the work pattern, the typical egg gallery consists of one short, longitudinal gallery arising from an enlarged entrance chamber, with the eggs very uniformly spaced along the sides and the larval mines extending laterally in a very regular pattern (fig. 77). Trees are attacked in the spring and summer, and there may be one or one and one-half generations a year. The only method of artificial control is to fell and burn the infested trees or severely scorch the bark. No control work has been attempted in the West, except in California for the control of a species affecting ornamental Monterey cypress. Approximately 20 species have been described from western cedars and related trees. Many of these are rare and of little economic importance.

The western cedar bark beetle (*Phloeosinus punctatus* Lec.) attacks the trunk and larger limbs of western red cedar, California incense cedar, and Sierra juniper in the mountains of the Pacific Coast States and eastward through the range of western red cedar. It is a common species and at times injurious to living trees. The galleries consist of either one short tunnel, not over 1 inch long, or two short tunnels in the form of a V. The beetles are dark red to black and about ⅛ inch long.

The juniper bark beetle (*Phloeosinus juniperi* Sw.) is black

FIGURE 77.—Small redwood tree scored by galleries of the redwood bark beetle (*Phloeosinus sequoiae*) and the roundheaded borer *Semanotus ligneus sequoiae.*

with reddish-brown wing covers and about 1/8 inch long. It attacks the trunks of Sierra juniper in California, Oregon, and Washington, making a short egg tunnel with a large nuptial chamber at the base. *P. rugosus* Sw. is a slightly smaller dark-brown species, which attacks the larger limbs of Sierra juniper in California. *P. scopulorum* Sw. breeds in Rocky Mountain juniper in British Columbia and southward into Washington. *P. utahensis* Sw. and *P. aciculatus* Bruck breed in junipers in Utah, Colorado, Arizona, and New Mexico.

The redwood bark beetle (*Phloeosinus sequoiae* Hopk.) (*70*) is also 1/8 inch long. It attacks weakened, felled, or fire-scorched redwood (fig. 77) along the coast of California and Oregon. *P. squamosus* Blkm. is a similar species which attacks Port Orford cedar and western redcedar along the coast from California to British Columbia. *P. nitidus* Sw. attacks Alaska yellow-cedar in Washington.

The sequoia bark beetle (*Phloeosinus rubicundulus* Sw.) works in broken branches of giant sequoias in their native groves in California.

The cypress bark beetles, *Phloeosinus cupressi* Hopk. and *P.*

cristatus Lec., are at times very destructive to Monterey and other cypresses in California. Besides killing many trees outright, they mine and kill the twigs of ornamentals, making them very unsightly. Other small species of cedar bark beetles which work mainly in twigs are discussed on page 39.

BARK BEETLES AFFECTING BROADLEAVED TREES

Certain species and genera of bark beetles confine their attacks to various broadleaved forest trees. Some of these are important enemies of shade trees, park trees, and ornamentals. Some of the more common are mentioned in the following paragraphs.

The alder bark beetle (*Alniphagus aspericollis* Lec.) is a common and often destructive enemy of western alders from British Columbia southward through California. The beetles usually attack weakened, dying, or felled trees. The adults are small, robust bark beetles about ⅛ inch long. They bore through the bark in pairs, usually at the base of branches, and construct a longitudinal egg gallery from 2 to 5 inches long, with no apparent nuptial cell. Eggs are placed close together along both walls of the gallery, with as many as 50 eggs to the inch. The larvae work out from the egg gallery and pupate in the soft inner bark. There appear to be two generations a year, and attacks occur throughout the growing season.

The ash bark beetle (*Leperisinus aculeatus* (Say)) breeds in felled, injured, or dying ash trees and under certain conditions may be injurious to living trees. It follows the distribution of its host trees from the Atlantic to the Pacific and has been recorded from Oregon, California, and New Mexico.[2] The adults are small, dark-brown bark beetles ⅛ inch in length, marked with grayish and dark scales. They construct uniform egg galleries beneath the bark with two transverse branches starting from a central entrance chamber. In the smaller limbs the galleries extend obliquely around the limbs and may completely encircle them. Ash bark beetles are frequently very abundant in ash cordwood.

The oak bark beetles (*Pseudopityophthorus* spp.) sometimes attack so heavily as to cause the death of weakened oak trees. Usually, however, these beetles confine themselves to injured, felled, or recently killed trees or to the dead branches and twigs of otherwise healthy trees. The adults are tiny, cylindrical, brown bark beetles. Their typical work consists of transverse egg galleries extending for a short distance on either side of the central entrance tunnel and diverging larval mines running longitudinally with the trunk or limb.

The birch bark beetle (*Dryocoetes betulae* Hopk.) is a secondary enemy of birch throughout British Columbia, Canada, and the northern part of the United States.

FLATHEADED BORERS

The flatheaded or metallic wood borers (Buprestidae) (*21*) comprise a large family of beetles, the larvae of which mine in

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[2] The western form of this species may represent a closely related undescribed species.

the inner bark and wood of many species of forest trees. Their activities are diversified. A few species attack and kill healthy trees by mining under the bark; others bore into the inner bark and sapwood of trunks, branches, and twigs of weakened and dying trees; while others breed only in dead or recently felled trees and make flattened, winding wormholes through the wood. A few species are leaf miners. In general, the group is a destructive one in that they sometimes kill living trees and often reduce the value of lumber by their attacks. Others assist materially in the natural process of disintegrating deadwood in the forest, and these are decidedly beneficial.

The adults are flattened, frequently brightly colored beetles with a metallic luster. They fly and mate and then lay their eggs in bark crevices or on the outer surface of the bark, early in the spring or in summer. When the eggs hatch the young grubs construct long, winding, oval mines in either the bark or the wood, or in both (fig. 78,*A*).

These mines gradually widen as the grubs increase in size, and end in elongated, oval pupal cells. The slender white grubs are the stage usually found in trees, and they can be recognized by their long, legless bodies, shaped like a horseshoe nail. The head is small, and the first segment back of the head is much broader than the following body segments and has horny plates on the top and bottom. Growth of the larvae continues until fall, when activity ceases with the advent of cold weather. The winter usually is passed in the larval stage, although some larvae may pupate in the fall and pass the winter as adults. Some species require 2 or even 3 or more years to complete their growth.

Since the beetles of this family have very diverse habits, only those species that attack and mine the inner bark of living trees are considered in this section. Species that work in the wood are more important from the standpoint of forest products and will be discussed in that section (p. 187).

For the control of flatheaded borers that mine in the inner bark, the same methods are used as for bark beetles. Infested trees usually are felled, peeled, and burned, and this work is frequently carried on in connection with the control of bark beetles.

The pine flatheaded borer (*Melanophila gentilis* Lec.) (*22*) is commonly found throughout the Western States, working beneath the bark of sugar, ponderosa, and Jeffrey pines. It is the species usually found infesting felled trees and logs, windfalls, and injured trees or occurring as a secondary species in the bole of standing trees. The bright, bluish-green adults are about ½ inch long. The larvae are white, legless grubs about 1 inch long. They are primarily bark-boring in habit and rarely enter the wood. On reaching maturity the larvae work out into the outer bark and pupate in oval cells close to the surface. There appears to be one generation annually.

The California flatheaded borer (*Melanophila californica* Van. D.) (*159*) (fig. 78) is primarily destructive to ponderosa and Jeffrey pines but may be found attacking knobcone, digger, Coulter, Monterey, and possibly other species of pine in California,

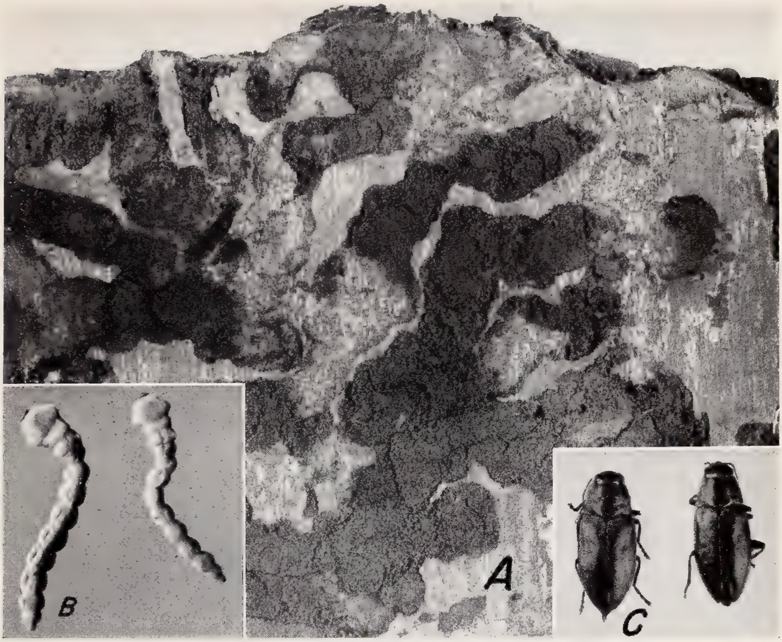

FIGURE 78.—The California flatheaded borer (*Melanophila californica*): *A*, Frass-packed channels in inner bark; *B*, full-grown larvae; *C*, adults. × 1.6.

Oregon, Washington, and Idaho. It attacks pines growing on rocky slopes, in fringe-type stands, or in other situations where soil moisture is insufficient for normal tree growth, most frequently attacking old, decadent, or unhealthy trees, but thrifty, vigorous trees are not immune. The adults are a greenish bronze and about ½ inch long. Eggs are laid in bark crevices of selected trees during the summer months. On hatching, the larvae bore into the cambium, where they may feed for a few months or for 3 or 4 years without apparent injury to the tree, except a scarring of the sapwood and a general weakening due to blocking of sap-conducting tissues. This is called the incipient stage. If they do not succeed in killing the tree, they finally die in this stage; but if the tree is overcome, the larvae pass into a fast-growing stage, begin to kill the cambium, and rapidly develop. Prepupal larvae appear in the outer bark in July and August, but new adults do not appear until April and May of the following year. This species is of primary importance in weakening trees and causing them to become increasingly susceptible to pine beetle attack.

The flatheaded fir borer (*Melanophila drummondi* Kby.) (fig. 79) is the species of this group most frequently found throughout the West attacking Douglas-fir, true firs, and hemlock. It also attacks western larch, spruce, and possibly other conifers. Though preferring trees that are dying or recently felled, the beetles some-

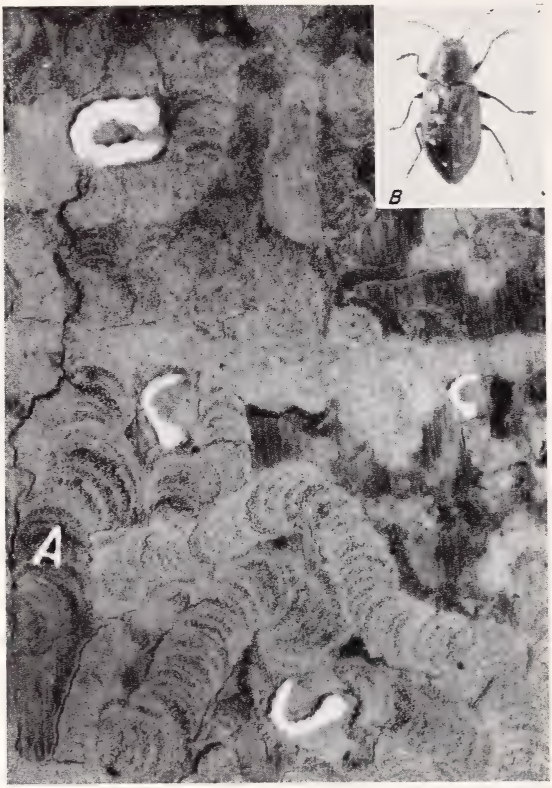

FIGURE 79.—The flatheaded fir borer (*Melanophila drummondi*): *A*, Inner bark showing larvae and concentric circles of frass-packed channels, natural size; *B*, adults, × 2.

times attack and kill apparently healthy trees. The adults are from ⅜ to ½ inch long and are metallic bronze or black with an iridescent sheen. Some of the beetles have bright golden spots on the wing covers. *M. pini-edulis* Burke works in dying or dead pinyon in Colorado, Utah, Arizona, and New Mexico.

Certain small, flat, nearly black metallic beetles, called firebugs are well known to fire fighters in the pine region on account of their prevalence around forest fires, where they gather in large numbers on the men's backs or bite them on the neck, arms, and hands (*102*). They appear to be strongly attracted by the smoke of forest fires; and during conflagrations, owing to some peculiar instinct, they try frantically to lay their eggs on the still smoldering trees. Several species of *Melanophila* have this habit (*6*), the most common offenders being *M. acuminata* DeG. and *M. consputa* Lec., which attack badly fire-scorched or weakened pines, spruces, firs, and other conifers, and even some hardwoods. The larvae feed in the inner bark.

There are many other species of flatheaded borers that feed in

and under the bark and do more or less damage to forest trees, but so far none of the western species have become of sufficient importance to require the application of control measures, and space does not permit listing them here.

ROUNDHEADED BORERS, OR LONG-HORNED BEETLES

The roundheaded borers, or long-horned beetles (Cerambycidae) (*35*), are an important group of forest insects, and include some very destructive species of tree-killing and wood-boring forms. Few of the western species, however, are serious enemies of living trees, although many species are injurious to forest products.

The adults are medium- to large-sized, oblong to cylindrical beetles, with antennae often longer than the entire body. These long antennae, or feelers, are their most characteristic feature and give them the name of "long-horned beetles." The name "roundheaded borers" comes from the structure of the larvae, which are white, long, slender, usually legless grubs with enlarged thoracic segments, and with a horny plate on the top surface of the first segment near the head, but with no plate on the under side of this segment. This distinguishes them from the flatheaded larvae, which in most species have a plate both above and below.

While many of the species are characteristically wood-boring in habit, one group confines its work to boring beneath the bark. Some of these bark-boring species are injurious to living trees, whereas others work in the bark of trees killed by other insects, or breed in the bark of felled, fire-killed, or wind-thrown trees. Some are beneficial in that they feed so voraciously on the bark that they rob the primary bark beetles of their food and thus starve out some of their young.

The adults deposit their eggs in bark crevices, and the young larvae bore through the bark and construct long, irregular mines in the bark and wood. These are increased in size with the growth of the larvae and are usually packed with the bark or wood fibers of the larval borings.

So far no attempt has been made to control these species in western forests, and few are ever aggressive enough to warrant such measures.

The roundheaded fir borer (*Tetropium abietis* Fall) is probably the most injurious roundheaded bark-boring species in western coniferous trees. The grubs are commonly found working under the bark of felled true firs and are sometimes suspected of being responsible for the death of standing trees. In the adult stage this insect is a velvety brown beetle about ¾ inch in length (fig. 80).

The western larch roundheaded borer (*Tetropium velutinum* Lec.) works between the bark and the wood of weakened larch and hemlock and is sometimes suspected of killing such trees. It is distributed throughout the Rocky Mountain and Pacific coast regions, where it also is found breeding in Douglas-fir and sometimes in spruce and pine. The adults are elongated, velvety-brown beetles about ½ inch long and are in flight from May to August. The larvae feed in the bark, where they construct irregular, winding mines which sometimes completely encircle the tree. During the

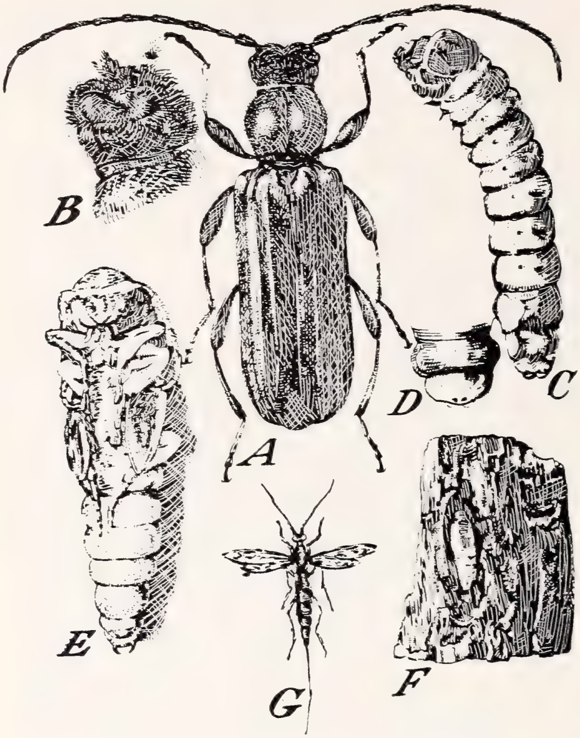

FIGURE 80.—The roundheaded fir borer (*Tetropium abietis*): *A*, Adult, × 3; *B*, detail of adult head, side view, × 4; *C*, larva, × 2; *D*, dorsal view of last abdominal segments of larvae, × 2; *E*, pupa, × 2; *F*, cocoon of parasitized larva in pupal cell, natural size; *G*, ichneumon parasite, natural size. (Drawing by Edmonston.)

later stages of larval development they may enter the wood to pupate, or they may pupate in the bark.

The ponderosa pine bark borer (*Acanthocinus spectabilis* Lec.) (fig. 81), in the larval stage is the large white grub so commonly found in ponderosa pines killed by the western pine beetle, and is sometimes mistakenly supposed to be the insect responsible for the death of the trees. It also occurs in other pines. These insects are more beneficial than otherwise, in that they rob the bark beetles of their food. The adults are large, speckled, gray beetles with extremely long feelers, and the female has a long, hornlike ovipositor extending from the end of the abdomen.

Acanthocinus obliquus Lec. is a smaller gray species with wavy markings on the wing covers. Its larvae feed under the drier bark at the tops of pines and spruces throughout the Western States.

The poplar borer (*Saperda calcarata* Say) (*69*), a reddish-brown beetle with dense gray pubescence, breeds in felled and weakened

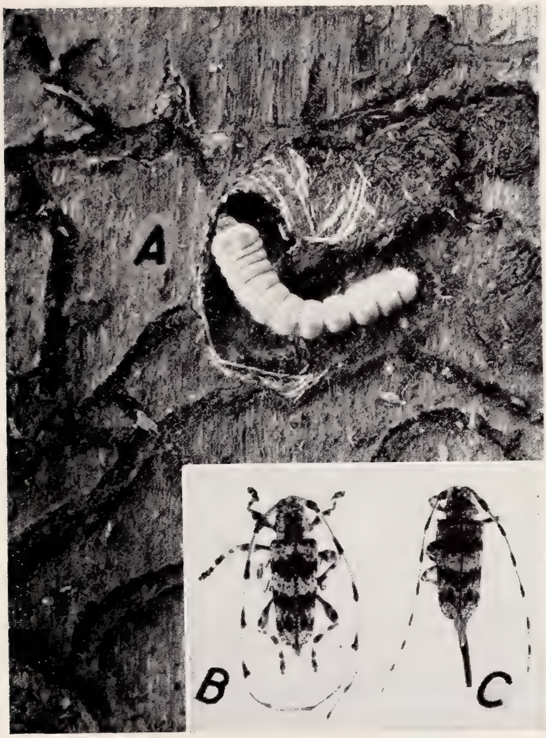

FIGURE 81.—*A*, Larva and work of the ponderosa pine bark borer (*Acanthocinus spectabilis*). The borings are shown crossing those of the western pine beetle. Insert: *B*, Male beetle; *C*, female beetle. All natural size.

aspen, poplar, cottonwood, and willows throughout most of the United States. The adults are elongate, robust, grayish beetles about 1 inch long, with faint yellowish spots on the elytra, and the antennae are at least as long as the body. The adults emerge late in July and in August. The female chews a slit in the bark, in which she deposits one or two eggs. The young larvae mine into the bark and remain there over winter. The following spring they enter the sapwood and heartwood, where they feed for 2 years. During this time they maintain an opening through the bark where the eggs were laid, and through this boring dust is expelled. When mature the larvae construct pupal cells near the lower end of the larval mines, and in these they remain inactive until the following spring. In July of the third year the adults emerge through the holes used by the larvae for expelling frass.

The amethyst cedar borer (*Semanotus amethystinus* (Lec.)) attacks California incense cedar, western redcedar, Port Orford cedar, and probably other cupressine trees in California, Oregon, Washington, and British Columbia. It usually selects injured or

dying trees, but sometimes appears to be responsible for the killing of apparently healthy trees. The adults are black, about 1 inch long, and have violet or bright-blue wing covers. *S. ligneus* (F.) is a black species ½ inch long, with orange or red marking on the wing covers. The variety *amplus* Csy. works under the bark of juniper, cedar, cypress, and giant sequoia in the West. The variety *sequoiae* Van. D. works in redwood in California. *S. juniperi* (Fisher) feeds under the bark and in the sapwood of juniper in the Southwest. *S. litigiosa* (Csy.) is similar, but confines its attacks to white fir, red fir, and Douglas-fir in the Rocky Mountain and Pacific Coast States.

Other species of bark-boring roundheaded beetles are as follows:

Species	*Hosts and distribution*
Atima dorsalis Lec.	California incense cedar and western red cedar. Pacific Coast States.
hoppingi Linsley	Alaska yellow cedar. Oregon and Washington.
huachucae Champl. & Knull	Arizona cypress. Arizona and New Mexico.
maritima Linsley	Monterey cypress. Coastal California.
Leptostylus nebulosus Horn.	True firs. Oregon and California.
Phymatodes decussatus (Lec.)	White oaks. Pacific coast.
dimidiatus (Kby.)	Douglas-fir, fir, larch, and hemlock. Pacific Coast and Rocky Mountain States.
lecontei Linsley	Oak. Pacific coast.
nitidus Lec.	Cypress, redwood, and California incense cedar. Pacific coast.
Semanotus juniperi (Fisher)	Juniper. Southern California and the Southwest.

BARK WEEVILS

Some bark weevils of the genus *Pissodes* (*74*) are particularly important as enemies of terminal shoots (p. 39); others attack the basal portion of the trunk of small trees and may extend their work into the roots. Weakened, suppressed, and decadent trees are usually preferred, but under some conditions these insects may attack healthy trees. Usually they breed under the bark of logs, in stumps, or under the bark of dying, standing trees and hence are of little economic importance (fig. 82).

The adults are stout beetles with uniform or variegated markings of yellow, brown, or black. The head is prolonged into a snout or beak, which is used to puncture buds and tender bark of terminal or lateral branches for feeding purposes, and in the female to make a hole for the reception of the eggs. The larvae are small, white, legless grubs, with curved cylindrical bodies. The larvae mine under the bark and form winding galleries, gradually increasing in size, which extend through the inner bark and sometimes score the sapwood. Each mine ends in a pupal cell constructed partly in the bark but mostly in the sapwood. This cell

FIGURE 82.—The Yosemite bark weevil (*Pissodes yosemite* Hopk.) : *A*, Typical work; *B*, adults. Slightly enlarged.

is oval in outline and is lined with excelsiorlike shreds of wood fiber. The nearly round larval mines and the "chip cocoons" are characteristic features of their work.

The adults are long lived and may deposit their eggs over a considerable period of time. The larvae, which reach maturity rapidly, usually within 2 or 3 months, may overwinter in the galleries or transform to adults that either overwinter under the bark or emerge and hibernate in the ground. There usually is but one generation annually.

Artificial control of the species in western forests has never been found necessary, as they are usually held in check by natural enemies and the limitation of suitable breeding material.

Bark weevils of the genus *Pissodes* that are most commonly found breeding under the thick bark at the base of small conifers, and the hosts in which they breed are as follows:

Species of *Pissodes*	Hosts and distribution
burkei Hopk.	Alpine fir. Rocky Mountains.
californicus Hopk.	Ponderosa pine. California.
coloradensis Hopk.	Spruces and western white pine. Rocky Mountains.
costatus Mann.	Sitka spruce. California to Alaska.
curriei Hopk.	Western white pine. Northern Rocky Mountains and northward into Canada.
fasciatus Lec.	Douglas-fir. California, Oregon, Washington, Idaho, and British Columbia.
murrayanae Hopk.	Lodgepole pine. Eastern Oregon, Washington, and the northern Rocky Mountain region.
piperi Hopk.	True firs. California, Oregon, Washington, Idaho, and British Columbia.
radiatae Hopk.	Monterery pine, Bishop pine, knobcone pine, and lodgepole pine. Pacific coast.
schwarzi Hopk.	Ponderosa pine. Rocky Mountain region.
webbi Hopk.	Ponderosa pine, Mexican white pine, and lodgepole pine. Southwest.
yosemite Hopk. (fig. 82)	Ponderosa pine, Jeffrey pine, sugar pine, and western white pine. California, Oregon, and Washington.

(See also terminal-feeding *Pissodes*, p. 39.)

PITCH MOTHS

Several species of moths, belonging to different families, attack the bole and larger limbs of living forest trees. Eggs are laid on wounds or on the bark surface, and the caterpillars which hatch therefrom mine into the inner bark and feed on the exudation of pitch. These larval galleries are filled with a thick, gummy pitch, and a large mass of pitch accumulates on the outside of the bark at the point of attack. Because of the character of their work they are called pitch moths. Some species are very injurious to the tops of trees, but most simply extend local wounds and do not threaten the life of the trees.

One large group of these pitch moths, or clear-winged moths, belonging to the family Aegeriidae, work in the inner bark and bore into the wood of various forest trees. They are called clear-winged moths because of the absence of scales on the wings and the general resemblance to wasps. The caterpillars are naked or have only a few prominent hairs. There are several important species which attack coniferous trees.

The sequoia pitch moth (*Vespamima sequoia* (Hy. Edw.)) (*15, 158*) attacks pines, Douglas-fir, and possibly other conifers in the Pacific Coast and northern Rocky Mountain States. Although the caterpillars of this moth are frequently found working in large pitchy masses on wounds of forest trees, the species is not a serious enemy. Sometimes breakage follows the attacks on small trees, or the pitchy, healed-over galleries cause defects in the lumber.

The adults are clear-winged moths about $\frac{2}{3}$ inch in length, somewhat resembling a wasp or yellow jacket, as the body is marked with yellow lines. The caterpillars are dirty-white or yellowish and about $\frac{3}{4}$ inch long when full grown.

The adults appear in the latter part of June and in July and

lay eggs in bark crevices or in mechanical wounds on the trees. The larvae start the construction of mines from the place where the eggs are laid and bore winding mines through the inner bark and the outer layers of wood. A large mass of gummy, sticky pitch, mixed with boring dust, exudes from the point of entrance. Two years are required to complete the life cycle, and the larvae pass both winters in their galleries. When mature the larvae transform to pupae within the pitch mass, and just prior to emergence the pupae push their way partially out, to permit the moths to emerge without coming in contact with the pitch mass.

The Douglas-fir pitch moth (*Vespamima novaroensis* (Hy. Edw.)) is a shining black species with a red spot on the under side of the abdomen. The caterpillars attack wounds on Douglas-fir throughout the range of this tree and have also been recorded from weakened larch and Sitka spruce. Like the sequoia pitch moth, the economic importance of this moth lies primarily in the subsequent lumber defects (*16*).

The adults are clear-winged moths with a wing expanse of 1¼ inches. They have spots of orange red on the thorax and bands of the same color on all the body segments except the last. The males are distinctly smaller than the females. The larvae are slender white caterpillars with brown heads, and when full grown range in length from 1 to 1½ inches. The larval skin is transparent, and in this respect the larvae differ from those of the sequoia pitch moth.

Brunner reports the appearance of the adults during the latter part of May and in June. The habits are comparable to those of the sequoia pitch moth, except that 4 years are required for development. Winters are passed by the larvae in their galleries, which are covered with large accumulations of pitch.

Some species of the family Pyralidae, or snout moths, work in the inner bark of various coniferous trees, causing a heavy exudation of pitch, and cause injury very similar to that of the clear-winged moths. Most of these do more serious damage to young trees than to older ones and therefore were discussed in the section dealing with young trees (p. 32).

INSECTS INJURIOUS TO WOOD AND OTHER FOREST PRODUCTS

Insects take a heavy toll of crude and finished forest products (*38, 73, 137, 145*). This loss has been variously estimated at 1 to 5 percent of the annual cut. The principal damage to forest products is caused by insects that feed on or bore into the wood. A great deal of this damage occurs after trees have been killed or felled, and before utilization. Green or seasoned lumber and even the final utilized products are fed on by insects.

After a tree has been killed by fire, insects, or other causes, or felled by wind, snow, or cutting, it becomes particularly attractive to a large variety of insects. Ambrosia beetles find the dying wood with fermenting sap an especially suitable medium for the growth of their fungi. Horntail wasps, or wood wasps, settle on freshly felled trees, sometimes before the woodsmen have finished cutting them into logs, and on fire-killed trees before the fire is out, and insert their long slender ovipositors deeply into the wood to lay their eggs. Many of the flatheaded and roundheaded borers, weevils, and larvae of carpenter moths and clear-winged moths are wood boring in habit. The larvae usually feed for a time in the cambium layer and then penetrate the wood. Fresh, unseasoned wood still containing sap, pitch, or other essential food elements is required for them. In short, so many different species of wood-boring insects start their work on killed or felled trees that it is important that such timber be peeled or promptly removed from the woods to avoid heavy damage.

After lumber has been kiln dried it becomes reasonably safe from insect attack. There are, however, a few important groups which still persist in their attacks unless the wood is properly handled. The seasoned sapwood of hardwoods is particularly susceptible to damage by powder-post beetles and must be carefully managed in the lumber yard or in storage to avoid becoming infested. Even after timbers are in place they are subject to attack by these insects, by carpenter ants, by certain roundheaded wood borers, flatheaded borers, and by termites unless precautions are taken to provide proper insulation from the ground or protection is secured through the impregnation of the wood with creosote or other chemicals.

As has been indicated, the control of insects injurious to forest products is largely a matter of prevention of damage through cutting at the proper season, prompt removal of logs, poles, and other unseasoned products from the woods, proper handling in the mills, and certain precautions in utilization. Logs that are to be used for poles or in rustic work should be peeled before wood borers have an opportunity to enter the wood. Some success has been obtained in repelling attacks of wood borers by spraying logs with coal-tar creosote diluted with 3 parts of kerosene (*34*). Better results may be had by thoroughly covering logs with a fuel-oil solution of benzene hexachloride containing 0.4 percent by weight of the gamma isomer. This treatment should give protection for 2 to 4 months. In cases where logs have been attacked, the insects can be killed by spraying with crude orthodichlorobeneze at full strength or paradichlorobenzene dissolved in 3 parts, by weight, of kerosene (*137*). All such treatments, however, give only a temporary immunity. More specific methods are discussed for each of the different insect groups.

Key to Diagnosis of Insect Injury to Wood and Wood Products

A. Insects attacking green, unseasoned, or seasoning wood, living or dying trees, or freshly felled trees or logs, and projecting their tunnels directly into and through the wood.

1. Small, circular, open pinholes, often surrounded by dark stains; diameter uniform and less than ⅛ inch; made by small, brown, shining, cylindrical beetles
Ambrosia beetles, p. 182

2. Large, more or less circular holes in wood; diameter more than ⅛ inch; lightly filled with pellets; wood stained or not.

a. Nearly circular holes of medium size in wood of broadleaved trees made by caterpillars
Clear-wing moths, p. 200

b. Very large irregular holes ½ to 1 inch in diameter in broadleaved trees, usually lined with a silky yellowish-brown web ....Carpenter moths, p. 198

3. Circular, oval, or irregularly shaped tunnels of varying width gradually increasing to more than ⅛ inch in size; usually tightly packed with fine boring dust or coarse frass, except at ends occupied by larvae or pupae.

a. Tunnels flatly oval, usually tightly packed with arc-like layers of sawdust-like borings and pellets of woody excrement, and surface of wood marked by fine, transverse, crescentric lines; made by slender, white, legless grubs shaped like horseshoe nails with very wide, flat segments back of head; first segment with a well developed plate on both upper and lower surfaces, upper plate marked with a central line, groove, V or Y
Flatheaded borers, p. 187

b. Tunnels broadly oval to nearly circular, tightly packed with sawdustlike borings and pellets of wood excrement; made by long, thick, white, apparently legless grubs, with horny plate on top of first thoracic segment, which is somewhat enlarged ....Roundheaded borers, p. 191

c. Perfectly circular holes in wood, not evident in cambium, made by long, white, cylindrical grubs with small heads, fleshy lobes for thoracic legs, and the abdomen terminating rearwards with a sharp horny prong
Horntails and certain Coleoptera, p. 200

B. Insects attacking living trees and causing black checks, pitch pockets, pitch flecks, gum spots, or ring distortion, but not causing pinholes or wormholes

1. Black checks showing in wood of conifers, surrounded by curled or distorted wood...............Bark maggots, p. 201
2. Birdseye pitch flecks in pine................Pitch midges, p. 70
3. Double rings, distorted rings, retarded growth[1]..Defoliators, p. 75
4. Pitch pockets, gum spots, and pitch streaks in coniferous woods ....Bark beetles, p. 129
Flatheaded borers, p. 169
Pitch moths, p. 178
Terminal-feeding insects, p. 35

Key to Diagnosis of Insect Injury to Wood and Wood Products (Cont.)

C. Insects attacking sawed lumber, seasoned wood, or wood products.
   1. Small wormholes in wood, tightly packed with a very fine powder, powder sometimes pushed out through holes in wood. Usually working in very dry wood.
      a. Small, nearly round tunnels in various hardwoods Powder-post beetles, p. 203
      b. Irregularly shaped tunnels in softwoods and hardwoods (see A, 3).
   2. Large cavities, lightly filled with excrement pellets or frass, not tightly packed with boring dust. Insects working in either dry or moist wood.
      a. Made by big black ants which leave only chewed wood fibers in cavities or push these out of the tunnels, leaving the same quite clean......Carpenter ants, p. 206
      b. Made by soft, antlike insects with white bodies and brown heads which usually leave many oblong impressed excrement pellets..............Termites, p. 208

[1] Also from causes other than insects.

INSECTS WORKING IN UNSEASONED LOGS OR LUMBER

AMBROSIA BEETLES

Ambrosia beetles (*82*) are important enemies of forest products because of their ability to riddle the sapwood and even the heartwood, of unseasoned logs or poles with small round pinholes or shot holes. These holes become surrounded with a dark-brown or black stain. The beetles of this destructive group belong to the families Scolytidae and Platypodidae. Although related to the bark beetles, they have very different habits.

The adults are small, reddish-brown to nearly black, cylindrical beetles that select for their attack dying or freshly felled trees, sawlogs, green lumber, or other unseasoned or moist wood such as stave bolts, or wine, beer, or vinegar casks. Small round tunnels are bored directly into the sapwood or heartwood; and since the beetles do not feed on the wood, the borings are cast out of the tunnels and collect on the surface of the bark or wood as a fine light-colored powder. The character of the tunnels varies with different species. Some construct an open, simple cavity; others a long, winding, circular gallery; while still others construct what is called a compound tunnel, with small pockets or larval cradles gnawed along the main channel. Into the tunnels, either intentionally or not, the adults carry the spores of certain fungi. These become detached, and, if moisture conditions are suitable, the fungi begin to grow along the walls of the galleries. Each species of beetle has its own specific ambrosial fungus, and the selection of trees for attack probably depends largely upon the requirements of the fungi. Some beetles specialize on certain species of trees, while others are more general in their attacks. As the fungi grow they are fed upon by the beetles and the developing larvae.

The living requirements of these insects are very exacting. If moisture conditions are not suitable the fungi fail to grow, and the beetles starve; or, if the fungi grow too abundantly, the beetles are unable to cope with them and are smothered in their own food. For this reason only moist, unseasoned wood is suitable for attack, and dried seasoned lumber is immune.

The shot holes, or pin holes, and accompanying stain are serious defects of high-grade lumber. In certain seasons ambrosia beetles on some Pacific coast logging operations have degraded 30 percent or more of the sapwood of Douglas-fir, Sitka spruce, and western hemlock, rendering it valueless for such uses as rayon pulp, airplane stock, and finishing lumber. Damage is usually greatest where mild winters give favorable temperature and moisture conditions for a long period of beetle activity. Where the winters are severe the beetles become inactive and thus a longer period may elapse between the time of cutting and the removal of logs, before damage becomes important.

The control of ambrosia beetles is largely a matter of prevention of damage through the regulation of woods practice and proper handling of the products from the mill. Logs cut in the summer or fall should be removed from the woods within a week or two after cutting and either placed in water or run through the mill (*109*). Logs cut late in the fall, in midwinter, or early in the spring will be reasonably safe until the approach of warm weather but often cannot be removed before damage has occurred. Freshly sawed lumber will be safe from attack if it is dried quickly, but some damage may occur in storage if the lumber is piled so as to remain or become moist. Logs or wood either heavily soaked with water or quite dry are not suitable for attack, but the exposed parts of logs left floating in ponds are very likely to become infested. In general, the control of these beetles is very difficult, and prompt utilization or kiln drying of the lumber is about the only satisfactory solution (*79*). A small amount of parasitism has been noted in studies connected with the work of these beetles in seasoned products, but it is of insufficient importance to reduce appreciably the number of beetles and the injury they cause.

Wilson's wide-headed ambrosia beetle (*Platypus wilsoni* Sw.) is very different from the other species in that the adults are long, slender, somewhat flattened, reddish-brown, shining beetles about ¼ inch in length, with a few long yellow hairs, projecting wing covers, and broad heads. They construct round, winding tunnels, of a few inches to a foot in length (fig. 83,*A*), into the sapwood and heartwood of dying, weakened, injured, or recently dead or felled true firs, Douglas-fir, spruce, and hemlock, and sometimes other conifers. At intervals along the main tunnel secondary tunnels branch horizontally. Eggs are deposited loosely in small clus-

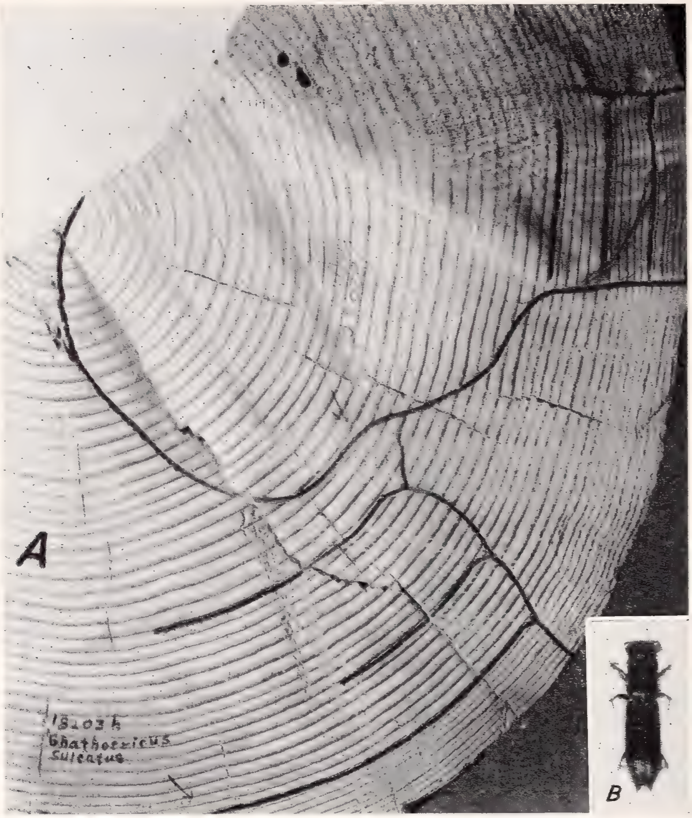

FIGURE 83.—Tunnels in fir made by ambrosia beetles: *A*, Long winding tunnel made by *Platypus wilsoni;* branching tunnels made by *Gnathotrichus sulcatus*. *B*, adult of *Platypus wilsoni* × 3.

ters in the tunnels, each female laying 100 or more. The young larvae wander freely about in the mines, feeding on the ambrosial fungus, and reach maturity in 5 or 6 weeks. When full grown they excavate cells at right angles to the main gallery in which to transform to pupae and adults. These cells are parallel to the grain of the wood and are often arranged in groups of 8 to 10 or more. This species is distributed throughout the Pacific coast region and Idaho, where it is the only representative of the family Platypodidae.

The wood stainers of the genus *Gnathotrichus* are small, cylindrical, dark-brown or black beetles of the size and appearance of a short piece of pencil lead. They attack nearly all species of conifers in the Western States, and one species works in alder. Their work is distinguishable from that of other western ambrosia beet-

les in that a primary tunnel penetrates the sapwood, and at intervals along this tunnel secondary tunnels branch horizontally, the branches more or less following the annual rings. The tunnels are of the compound type, in that larval cradles are constructed at regular intervals, both above and below the primary and secondary galleries. The species so far recorded in the West are as follows:

Species of *Gnathotrichus*	*Hosts and distribution*
aciculatus Blkm.	Pines, Douglas-fir, and white fir. Rocky Mountains and Southwest.
alni Blkm.	Alder and poplar. Western Oregon and Washington.
denticulatus Blkm.	Pines and white fir. Southwest.
retusus Lec.	Pines, Douglas-fir, and hemlocks. Rarely in firs and spruce. Pacific coast and northern Rocky Mountains.
sulcatus Lec. (fig. 83)	Spruce, hemlock, Douglas-fir, and true firs; sometimes also pines, redwood, cedar, and other conifers. Western States.

The ambrosia beetles of the genus *Trypodendron* are small, stubby, dark-colored beetles, with a roundish prothorax and a smooth, more or less shining body, often with lighter colored longitudinal stripes. They attack the wood of many species of coniferous and broadleaved trees and are distributed throughout the greater part of the United States and Canada. Their galleries (fig. 84) are of the compound type with larval cradles arranged in series both above and below the main tunnels, which branch in a horizontal plane and cut across the grain of the wood.

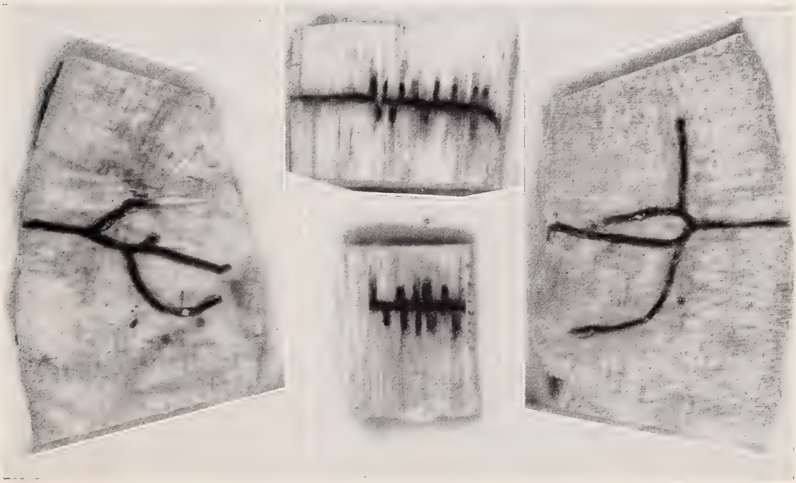

FIGURE 84.—Typical tunnels and larval cradles made by the ambrosia beetle *Trypodendron borealis* Sw. in the sapwood of western white pine.

The species most frequently encountered in the Western States are as follows:

Species of *Trypodendron*	Hosts and distribution
bivittatum (Kirby)	Pines, spruce, hemlock, Douglas-fir, and other conifers. Pacific coast and Rocky Mountain regions.
borealis Sw.	White spruce, Engelmann spruce, western white pine, and white-bark pine. Northern Rocky Mountains.
cavifrons (Mann.)	Douglas-fir, fir, spruce, hemlock, western red cedar, alder, and poplar. Pacific Northwest.
ponderosae Sw.	Ponderosa pine, Engelmann spruce, Douglas-fir, alpine fir, Pacific white fir, and mountain hemlock. British Columbia and south into Oregon.
retusum (Lec.)	Poplar and aspen. Canada and Northwestern States, and east to West Virginia.
rufitarsis (Kirby)	Lodgepole pine. Idaho, Montana, Oregon, and Washington.

The oak timber beetles, of the genus *Monarthrum* (*Pterocyclon*), are small, elongate, cylindrical, dark-brown ambrosia beetles, which work in the wood of oak and various other hardwoods and deciduous trees. After the beetles have entered the wood, they excavate a central nuptial chamber from which secondary tunnels branch in three or four directions. From the secondary branches the larval cradles are excavated at right angles and parallel to the grain of the wood. *M. scutellare* (Lec.) (fig. 85), about 1/8 inch

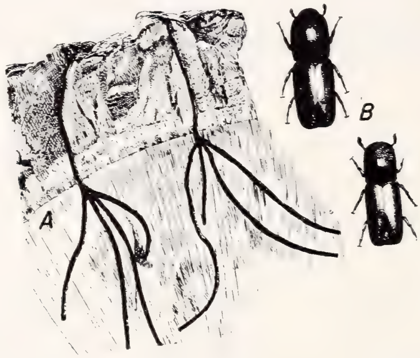

FIGURE 85.—The oak timber beetle *Monarthrum scutellare*: *A*, Tunnels; *B*, adults, male above, female below, × 8.

long, works in various species of oak from Oregon to southern California. *M. dentiger* (Lec.) is a smaller species, about 1/16 inch long, which works in oak trees in California.

Species of *Xyleborus* make very small pinholes in the dying or dead wood of a wide assortment of fruit, shade, and forest trees. Larval cradles are not formed, and the tunnels are either plain or enlarged into cavities where the larvae feed. Most frequently their work is found in dying or recently dead wood. *Xyleborus scopu-*

lorum Hopk. works in the dead wood of ponderosa pine, Jeffrey pine, and Coulter pine in California, Oregon, and South Dakota. *Xyleborus arbuti* Hopk. works in madrone, maple, and alder in California and Oregon. *Xyleborinus saxeseni* (Ratz.) attacks a large variety of hardwoods and is widely distributed in both Eastern and Western States. The galleries consist of simple branching tunnels in which the larvae live and feed upon ambrosial fungus without constructing an enlarged cavity or larval cradles. *Xyleborinus librocedri* Sw. attacks the wood of California incense cedar in Oregon, and *Xyleborinus tsugae* Sw. works in the wood of western hemlock.

FLATHEADED WOOD BORERS

The flatheaded borers (Buprestidae) have been previously discussed under the section on cambium or inner-bark miners (p. 169). By far the larger number of species, however, are of more economic importance as wood borers than as killers of living trees. Many species work first in the inner bark of dying trees, then extend their tunnels into the sapwood, and even into the heartwood. The flattened oval wormholes made by the horseshoe-nail-shaped grubs are usually tightly packed with boring dust and may wind in a tortuous fashion back and forth through the wood so as to riddle it completely. Even a few such wormholes greatly lower the quality of the lumber, and a large number make it unfit for any but the roughest use. Some of these wood borers attack the pitchy fire scars on living trees and gradually extend their mines into the sounder portions. Many others attack trees that have been killed or felled and do most of their damage while the wood is still unseasoned. Others will attack wood after it has been run through the mill and is placed in storage, or even after it has been put into use.

The prevention of fire scars and other injuries to standing trees and the prompt utilization of dead or felled trees will reduce this damage to a low point. In wood that has become infested after being put into place, the grubs usually can be reached and killed by liberal applications of crude orthodichlorobenzene or kerosene.

The sculptured pine borer (*Chalcophora angulicollis* Lec.) (fig. 86) is the largest of the western species of flatheaded borers and

FIGURE 86.—The sculptured pine borer (*Chalcophora angulicollis*). Natural size.

the only western representative of this genus. The adults are over 1 inch long and dark brown to black, with an iridescent bronze luster, especially on the under side. The upper surface is marked with irregularly sculptured areas. Many a woodsman has been startled on a warm summer day to have one of these large beetles suddenly take flight with the noise of a small airplane from its quiet resting place on a nearby tree trunk. The larvae feed in the wood of dead pines, firs, and Douglas-fir throughout the Western States.

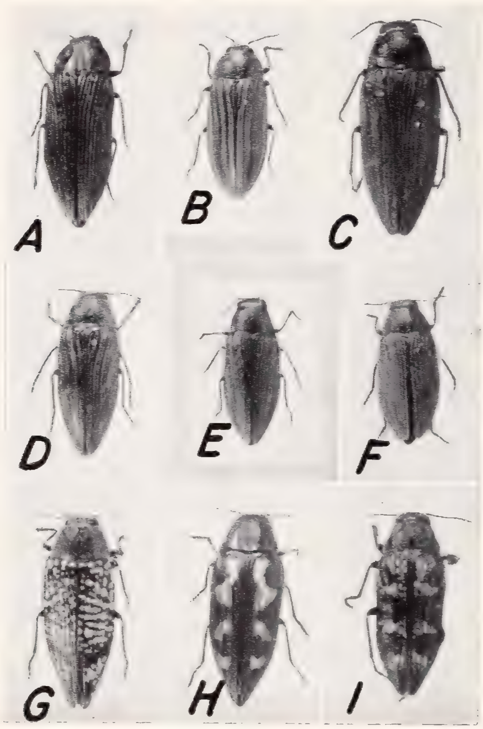

FIGURE 87.—Adult flatheaded wood borers of the genus *Buprestis*: *A*, *langi;* *B*, *aurulenta;* *C*, *rusticorum;* *D*, *subornata;* *E*, *connexa;* *F*, *adjecta;* *G*, *confluenta;* *H*, *nuttalli laeviventris;* *I*, *nuttalli*. All × 1.5.

The golden buprestid (*Buprestis aurulenta* L.) (fig. 87,*B*) is one of the most destructive species in this group. The adults are beautifully colored beetles ½ to ¾ inch long, with a flattened oval body and an iridescent green or bluish color, with all margins bordered with copper. They are particularly attracted to pitchy wood and lay their eggs on fire scars or the exposed pitchy wood of pines, spruces, firs, Douglas-fir, and other conifers. Flooring and woodwork of Douglas-fir that is not heavily covered with paint or

varnish sometimes is repeatedly attacked until the interior is completely riddled and destroyed. If the wood is very dry, it takes many years for the larvae to complete their development—rearings indicate more than 10 years—and many records of emergence from wood in houses indicate from 10 to 26 years (*103*). *B. langi* Mann. (fig. 87,*A*) is a bright-green species which has the same habits as the golden buprestid and is found attacking Douglas-fir throughout the Pacific coast and Rocky Mountain regions.

Ten other species in this genus of highly colored beetles do similar damage to the wood of western forest trees (fig. 87). They are as follows:

Species of *Buprestis*	*Hosts and distribution*
adjecta (Lec.) (fig. 87, *F*) ...	Ponderosa, lodgepole, and possibly other pines; Douglas-fir and red fir. Western States. Uncommon.
confluenta Say (fig. 87, *G*) ..	Poplar and aspen. Western States. Uncommon.
connexa Horn (fig. 87, *E*) ..	Ponderosa and Jeffrey pine. Pacific coast and Idaho. Rare.
gibbsi (Lec.)	Oak. Pacific coast. Rare.
intricata Csy.	Lodgepole pine. California, Wyoming, Colorado, New Mexico, and British Columbia. Uncommon.
nuttalli (Kby.) (fig. 87, *I*) ..	Ponderosa pine and Douglas-fir. Pacific coast. Rocky Mountain States, and in the East.
nuttali subsp. *laeviventris* (Lec.) (fig. 87, *H*)	Pines and Douglas-fir. Western States. Common.
rusticorum (Kirby) (fig. 87, *C*)	Fir, Douglas-fir, and pines. Western States. Common.
subornata (Lec.) (fig. 87, *D*)	Ponderosa and lodgepole pines. Western States. Uncommon.
viridisuturalis N. & W.	Poplar, cottonwoods, and alder. California, Oregon, and Washington. Common.

FIGURE 88.—Adults of a flatheaded wood borer, *Dicerca tenebrosa*. Natural size.

The dicerca beetles, members of the genus *Dicerca* (fig. 88), are medium-sized, robust, roughly sculptured, metallic, wood-boring beetles of a dull bronze color, with the tips of the wing covers prolonged into narrow points. The larvae work under the bark and into the wood of various species of trees that are sickly, dying, or dead. Of the 10 species recorded from the Western States, those

most frequently found breeding in the wood of forest trees are the following:

Species of *Dicerca*	*Hosts and distribution*
crassicollis Lec.	Douglas-fir. Pacific States.
divaricata (Say)	Alder, birch, and other broadleaved trees. Colorado and Utah.
horni Crotch	Alder, sycamore, and other broadleaved trees and shrubs. Pacific States and northern Rocky Mountains.
prolongata Lec.	Aspen, cottonwood, poplars, alder, and other broadleaved trees. All Western States.
sexualis Crotch	Douglas-fir, ponderosa pine, Jeffrey pine, and knobcone pine. New Mexico, Arizona, California, Oregon, and Washington.
tenebrosa (Kirby) (fig. 88)	Pines, true firs, Douglas-fir, and Engelmann spruce. California, Oregon, Washington, Idaho, Montana, and Eastern States.

The western cedar borer (*Trachykele blondeli* Mars.) (*23, 76*) mines in the sapwood and heartwood of living, dying, or dead trees of western redcedar, cypress, California incense cedar, and related species and is very destructive to trees used for poles, shingles, cooperage, ship-building, or other purposes where sound wood is required. The adults, which are roughly sculptured beetles about ⅝ inch long, of a very beautiful, bright emerald green with a golden sheen, lay their eggs on the wood of scars on the trunk or branches of standing trees, and the flatheaded larvae mine about in the wood for a period of 2 or 3 years before reaching maturity. The newly formed beetles remain in the wood for about 6 months, from September to May, before they emerge and start a new generation. There is no practical means of control under present forest conditions. The variety of *juniperi* Burke is found in junipers in California.

Three other species of this genus are found in the Western States doing similar work in various cedarlike trees:

Species of *Trachykele*	*Hosts and distribution*
nimbosa Fall	True firs and mountain hemlock. California, Oregon, Washington, Idaho, and British Columbia.
opulenta Fall	California incense cedar, western redcedar, giant Sequoia, and related trees. California, Oregon, and Washington.

There are 115 or more species of small flatheaded borers of the genus *Chrysobothris* that bore in the bark and wood of limbs and trunks of various weakened, dying, or dead conifers and broadleaved trees. Only a few of these are of sufficient importance to warrant specific mention. **The cedar flatheaded borer** (*Chrysobothris nixa* Horn) is a common enemy of California incense cedar, Sierra juniper, and cypress in the Pacific coast region. *C. californica* Lec. works in the exposed roots of ponderosa and

Jeffrey pine in California. Other common western species of *Chrysobothris* include:

Species	*Hosts and distribution*
breviloba Fall	Ponderosa, pinyon, limber, and lodgepole pine, and Douglas-fir. Rocky Mountain region.
carinipennis Lec.	Douglas-fir, probably also pines and larch. Rocky Mountain region.
caurina Horn	Ponderosa, sugar, and Jeffrey pine, and other conifers. Western States.
dentipes (Germ.)	Pines. North America.
dolata (Horn)	Ponderosa pine, fir, and Douglas-fir. Pacific coast and Idaho.
falli V. D.	Lodgepole pine. California and Oregon.
ignicollis Horn	Juniper and cypress. Rocky Mountain region and Southwest.
monticola Fall	Pines. Pacific coast and northern Rocky Mountain region.
octocola Lec.	Mesquite. Southwest.
pseudotsugae Van D.	Firs and Douglas-fir. California, Oregon, and Idaho.
semisculpta Lec.	Ponderosa, Jeffrey, and sugar pine. Pacific Coast States.
sylvania Fall	Douglas-fir. California, Oregon, and British Columbia.
texana (Lec.)	Juniper and cypress. Southwest, California, Utah, and Colorado.

Other western genera of wood-boring buprestids that may cause damage of some economic importance are listed below:

Genus	*Hosts*
Acmaeodera	About 18 species in various broadleaved trees and shrubs.
Poecilonota	About 5 species which breed in willows, poplars, cottonwoods, and alder.
Polycesta	Four or more species in broadleaved trees and shrubs.

(See also bark-, twig-, or cone-boring buprestids, pp. 23, 46, 169.)

ROUNDHEADED WOOD BORERS

The roundheaded borers or long-horned beetles (Cerambycidae) (*33*) have been previously discussed (p. 173) under the section Miners in the Inner Bark and Phloem. The western members of this family, however, are much more important from the standpoint of damage to forest products than in the role of killers of living trees. Most of the species are typically cambium-wood insects, in that the larvae first mine in the cambium region of dying or dead trees and then extend their tunnels into the sapwood and in some cases into the heartwood. The large, broadly oval worm holes are a serious defect in lumber, and if these are numerous the wood becomes worthless for lumber purposes. Dying or dead trees, those killed by insects or fire, or trees felled in cutting

or by windstorms are most frequently selected for attack; and if such timber is not promptly removed from the woods, it may soon be completely ruined for commercial purposes. The salvage of fire-killed trees frequently depends upon the rapidity with which they can be removed from the danger of attack by these borers. Unpeeled logs left in the woods during certain seasons of the year are often seriously damaged.

There is no way in which these insects can be controlled in the woods, and there seems little likelihood that practical methods will be developed that will prevent attack on dead or dying trees or recently felled logs. As with other insects that attack unseasoned wood, about the only thing that can be done is to remove the logs from the woods as quickly as possible and place them in water or run them through the mill and kiln-drying process. A few of these insects, however, are of importance even after the lumber is placed in storage.

The ponderous borer (*Ergates spiculatus* Lec.) is very destructive to the wood of recently killed or felled coniferous trees, to fallen logs and stumps, and even to power and telephone poles. It has been found to be an important determining factor in the salvage of fire-killed Douglas-fir (*96*). The heartwood of this tree is very resistant to deterioration until penetrated by the large mines of this wood-boring species. The adults are the largest of our western beetles, measuring from 1½ to 2¼ inches in length (fig. 89). The color is uniformly dark brown, with the head and

FIGURE 89.—The ponderous borer (*Ergates spiculatus*): *A*, Larvae; *B*, adult female. Natural size.

thorax somewhat darker than the wing covers. The sides of the prothorax are armed with a few large or many small teeth or spines. They are often found flying around lights early in the summer. Eggs usually are laid in crevices of the bark of dead trees or stumps, and the larvae excavate large channels and pack them with coarsely chewed wood fiber, in the sapwood and then into the heartwood. When full grown the large, thick-bodied larvae are often 2½ inches in length, creamy white, with reddish heads bearing plates armed with four spines just above the mandibles. The species is found throughout the Western States, commonly attacking Douglas-fir and pines.

The California prionus (*Prionus californicus* Mots.) is similar to the ponderous borer. The larvae feed in the roots of oak, alder, poplar, and other hardwoods, and also in such coniferous roots as pine, redwood, Douglas-fir, and fir. Sometimes they bore into the roots of living trees. The adults usually have three prominent spines on the lateral margins of the prothorax. It is distributed in the Pacific coast region from Alaska through California and eastward into the Rocky Mountain region and the Southwest.

Tragosoma harrisi Lec. is a more slender reddish-brown beetle about 1¼ inches long, which breeds in the sapwood of dead lodgepole, ponderosa, and other pines in the colder parts of the West.

The larvae of the genus *Monochamus,* known as sawyers, are responsible for extensive damage to dying and recently killed and felled trees throughout the United States. The females chew irregular pits in the bark, and in these from one to six eggs are placed. The larvae, which are elongated, footless, whitish grubs, feed from 4 to 8 weeks between the bark and wood, loosening the bark and filling the space between bark and wood with long fibrous borings. Later the larvae enter the wood, forming small oval holes, that become nearly round as the larvae mature. These tunnels extend through the sapwood, often into the heartwood, and then turn outward to the bark several inches from the point of entrance, thus, making U-shaped burrows in the wood. During the early stages of larval development the borings are dropped from the galleries and form small piles of sawdust. As the larva nears maturity the borings are no longer ejected, and the galleries are packed solid, with the exception of a small cell at the end of the gallery in which pupation occurs. The mature adult emerges by gnawing a round hole through the thin layer of wood and bark which separates the pupal cell from the surface. Though the life cycle of these insects is usually completed in 1 year, in the northern portion of the range two seasons are often required. The adult beetles, during flight and egg laying, feed upon the needles of conifers, and some species gnaw the bark from young twigs, many of which are killed.

The spotted pine sawyer (*Monochamus maculosus* Hald.) (fig. 90) is from ½ to 1 inch long, drab-brown, with grayish, irregular-shaped markings. The prothorax is of the same width as the head and has a prominent toothlike projection on each side. The larvae, which range from 1 to 1¾ inches in length, are destructive to fire-

FIGURE 90.—The spotted pine sawyer (*Monochamus maculosus*), males. Natural size.

scorched, dying, or recently felled pines and Douglas-fir throughout the Western States.

The Oregon fir sawyer (*Monochamus oregonensis* Lec.) (fig. 91) is a stout, black beetle, approximately ½ to 1¼ inches long, with gray markings, antennae about twice as long as the body, and a toothlike projection on each side of the prothorax. The larvae range from 1 to 1¾ inches in length and are destructive to fire-scorched, injured, dying, or recently felled Douglas-fir, true firs, and pines of the Western States. This is the western variety of the eastern white-spotted sawyer (*M. scutellatus* Say).

The obtuse sawyer (*Monochamus obtusus* Csy.) is a small brown beetle with gray markings, measuring from ½ to ¾ inch in length. The antennae are over twice as long as the body, and the prothorax has a toothlike projection on each side. The larvae are from 1 to 1½ inches long and are destructive to pine, Douglas-fir, and fir in the Pacific Coast States, British Columbia, and Idaho.

The black-horned pine borer (*Callidium antennatum* var. *hes-*

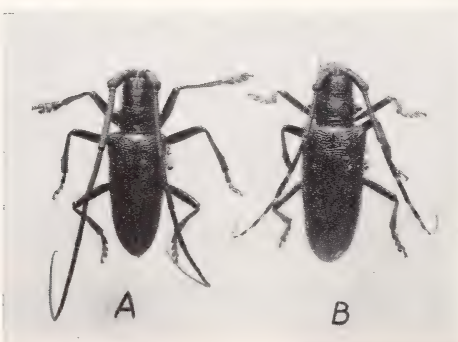

FIGURE 91.—The Oregon fir sawyer (*Monochamus oregonensis*): *A*, Male; *B*, female. Natural size.

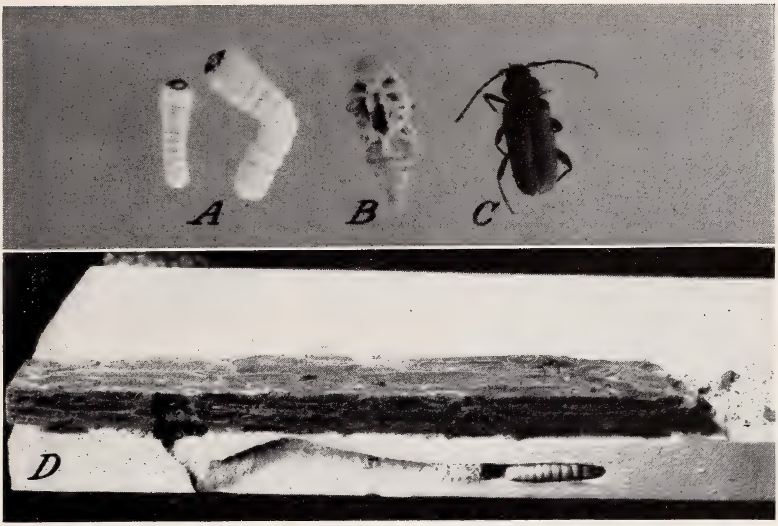

FIGURE 92.—The black-horned pine borer (*Callidium antennatum*): *A*, Larvae; *B*, pupa; *C*, adult; *D*, larval damage to pine board where bark edging remains.

perum Casey) (*121*) (fig. 92) is a common species in western forests, attacking the logs and limbs of dead ponderosa pine, sugar pine, and Douglas-fir. It attracts attention occasionally as a destructive borer in lumber stored in mill yards, where it attacks strips of bark left on the edges of lumber stock. The larvae work under this bark and score the surface of the wood, then extend their mines into the sapwood for a depth of 2 or 3 inches. They also injure seasoned rustic work by mining out the cambium layer and causing the bark to loosen from the log. The larvae are yellowish-white, apparently legless grubs about ¾ inch long when full grown. The adults are flat, shining, bluish-black beetles about ½ inch long, with antennae about half as long as the body. Other closely related species of *Callidium* attacking the limbs of various firs, pines, cedars, redwood, and junipers are discussed under the section on Twig Borers on page 47.

Callidium pallidum Van D. has been reported as working in the stumps of redwood in California.

Arhopalus productus (Lec.) is a narrow black beetle about ¾ inch long. The white larvae mine under the bark and into the sapwood and heartwood of fire-killed Douglas-fir, causing much damage to the wood and often limiting its salvageability (*96*). It is also found in pines throughout the Pacific coast and eastward into Montana. *A. asperatus* (Lec.), a larger, more robust species with roughened prothorax (fig. 93), does similar work in true firs and spruce in the same regions.

The black spruce borer (*Asemum atrum* Esch.) is the most abundant species found attacking the heartwood of Douglas-firs killed by fire, especially in the early years (*96*). The adult beetles

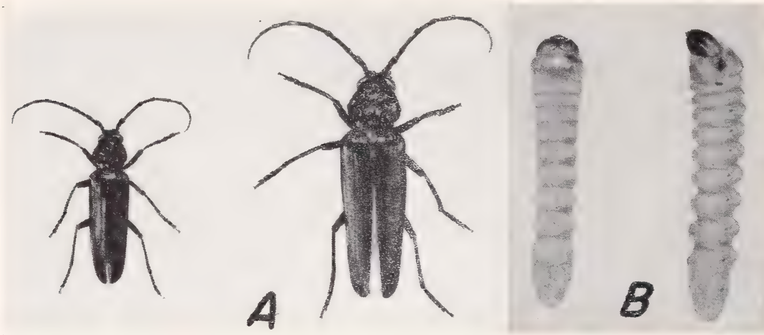

FIGURE 93.—The roundheaded borer *Arhopalus asperatus*: *A*, Adults; *B*, larvae. Natural size.

are black and about ½ inch long. The mature larvae, which are about 1 inch long, mine under the bark, then extensively in the sapwood, making tunnels oval in outline, and later extending their borings into the heartwood for 6 to 8 inches. This species also mines the wood of pines and Sitka spruce and is distributed throughout the Pacific Coast and northern Rocky Mountain States. *A. nitidum* Lec. is a larger, smoother, dark-brown to black beetle, which in the larval stage does similar work in pines of the Pacific coast. *A. mokelumne* (Csy.) is a similar species found in ponderosa and Jeffrey pines of the Sierra Cascade ranges. *Megasemum asperum* (Lec.), a longer, more cylindrical, dark reddish-brown beetle, in the larval stage also bores in Douglas-fir in the Western States.

Spondylis upiformis Mann. is a dull black, robust beetle from ½ to ¾ inch long and with rather short antennae. The larvae bore in the exposed roots and wood of ponderosa pine, sugar pine, western white pine, and lodgepole pine in the Pacific Coast and northern Rocky Mountain States.

The spruce limb borer (*Opsimus quadrilineatus* (Mann.)) is a dark brown long-horned beetle from ⅝ to ½ inch long, and with four ridges on each wing cover. The larvae bore under the bark and into wood of suppressed branches of Sitka spruce, Douglas-fir, true firs, shore pine, and Monterey cypress along the Pacific coast from California to Alaska. It also has been reported damaging the seasoned wood of rustic homes in Oregon (*53*).

The lion beetle (*Ulochaetes leoninus* Lec.) in the adult stage is about 1 inch long and has very short, aborted black wing covers tipped with yellow, which fail to cover the delicate underwings. In appearance it looks more like a bumblebee than a beetle. The larvae bore in the roots of pines, Douglas-fir, firs, and spruce in the Pacific Coast States.

Long-horned beetles of the tribe Lepturini are very numerous as to species, and most often are found visiting flowers. Most of them are of little economic importance, since the larvae feed on old decaying wood. *Leptura obliterata* Hald. has been found in abundance in fire-killed Douglas-fir (*96*), extending the deteriora-

tion into sound wood. The larvae are creamy-white and about 1 inch long when full-grown. The adults are dark brown to black with various yellow markings. They have also been found working in redwood, Sitka spruce, western hemlock, and other conifers in the Pacific Coast States.

Long-horned beetles of the genus *Xylotrechus* are stout and cylindrical, with antennae only slightly longer than the head and thorax and with wavy, zigzag, or crescent-shaped markings across the wing covers. The larvae of *X. undulatus* (Say) bore in Douglas-fir, larch, spruce, and hemlock in the Pacific Coast and northern Rocky Mountain States. The adults are from ½ to ¾ inch long with black, sharply outlined white markings on the wing covers. *X. abietis* Van D. is similar to the above with more indistinct smoky-white markings. The larvae bore in the true firs. *X. nauticus* (Mann.) (fig. 94,*A*) is a dark-brown beetle with lighter

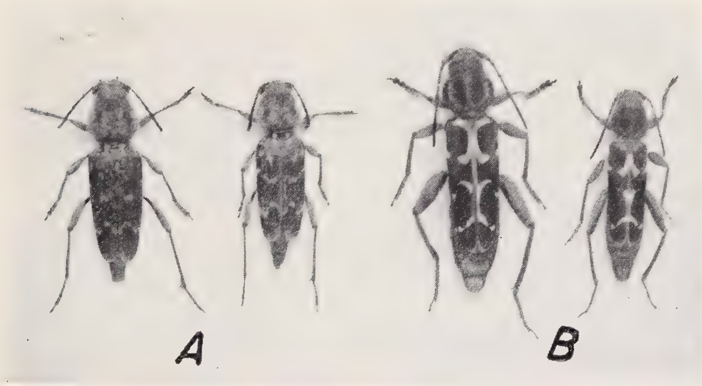

FIGURE 94.—Roundheaded wood borers: *A, Xylotrechus nauticus; B, Neoclytus conjunctus,* × 2.

markings and is from ½ to ⅝ inch long. The larvae commonly bore in oak and madrone, especially in firewood, in California, Oregon, and eastward into Montana. *X. insignis* Lec. is a velvety-brown beetle with bright yellow markings and is ½ to ¾ inch long. The larvae bore in willow in California, Oregon, Nevada, and Arizona. *X. annosus* (Say), a gray species with white markings, breeds in aspen, poplar, and willow in the Rocky Mountain and Pacific Coast States. *X. obliteratus* Lec. is a serious pest of aspen and poplar in the Rocky Mountain region. The larvae work under the bark and into the wood, especially at the base of trees, and attacks are repeated until the heartwood is completely honeycombed and the trees break off during wind or snow storms. Extensive areas of aspen above 7,000 feet in Colorado and Utah have been killed by this species. The adults are from ½ to ¾ inch in length, and are dark with three yellow bands across the wing covers.

Other species of wood-boring cerambycids that may be encoun-

tered damaging the wood of western broadleaved forest trees are the following:

Species	*Hosts and distribution*
Brothylus gemmulatus Lec.	White and black oaks. Colorado and California.
Malacopterus tenellus (F.)	Willow and poplar. Arizona and southern California.
Megacyllene antennatus (White)	Mesquite. Southwest.
Necydalis cavipennis Lec.	Oak, alder, and other hardwoods. Pacific coast and Arizona.
Neoclytus caprea (Say)	Ash, oak, and mesquite. California, Utah, Arizona, and Colorado.
conjunctus (Lec.) (fig. 94, *B*)	Oak, ash, and madrone. Western States.
Rosalia funebris Mots.	Alder, ash, California laurel, willow, and sycamore. California to Alaska, and New Mexico.
Synaphaeta guexi (Lec.)	Oak, poplar, maple, and willow. Pacific coast.

The blazed tree borer (*Serropalpus barbatus* (Schall.)) of the family Melandryidae, lays its eggs in dying or dead trees or living trees from which the bark has been peeled. The long, slim, white larvae mine the sapwood, making oval tunnels filled with very fine dustlike frass. After two seasons in the larval stage, the slender reddish-brown beetles, ½ to ¾ inch long, emerge in June and July through perfectly round holes cut in the bark. This wood borer is widely distributed throughout North America, breeding in various coniferous trees. In the West it has been bred from red fir, California incense cedar, lodgepole pine, ponderosa pine, redwood, Port Orford cedar, Engelmann spruce, and Douglas-fir, and probably will be found in many other conifers.

WOOD-BORING WEEVILS

Some of the weevils (Curculionidae) belonging to the genera *Rhyncolus, Cossonus, Pissodes,* and *Cryptorhynchus* are found at times working in wood. The work of *Pissodes* has been previously mentioned (pp. 39 and 176). The *Rhyncolus* and *Cossonus* weevils are small brown or black weevils less than ¼ inch long, with the head produced into a snout. The larvae are white, legless, and comma-shaped. Both adults and larvae may be found boring into and destroying wood, but, as the wood is usually decaying, they are seldom of economic importance.

The poplar and willow borer (*Cryptorhynchus lapathi* (L.)) (*110*) bores under the bark and into the wood of poplars and willows, making irregular more or less cylindrical tunnels which often so riddle the wood as to cause heavy breakage. The adults are rough, dark-colored weevils about ¼ inch long, with a band of bright pink across the tip of the wing covers. This is an introduced species which is gradually becoming widely distributed throughout the country. It is now prevalent in western Oregon, Washington, and Idaho.

CARPENTER MOTHS

The larvae of some families of moths mine directly into the wood of injured or weakened trees, where they may cause additional in-

jury which may kill the tree. These injuries to the living tree often appear as serious defects when the tree is converted into lumber. The carpenter moths, belonging to the family Cossidae, principally attack broadleaved forest, shade, and fruit trees. The adults are large, mottled-gray moths, with spindle-shaped bodies and narrow, strong wings of medium to large size. They are night fliers and lay their eggs in bark crevices or on old wounds. The caterpillars, which are nearly hairless, have both true legs and abdominal prolegs but are somewhat grublike in form. Pupation occurs within the larval gallery, and when about ready to change to the adult the pupa works partially out of the burrow, so after emergence the empty pupal skin is found protruding from the tunnel.

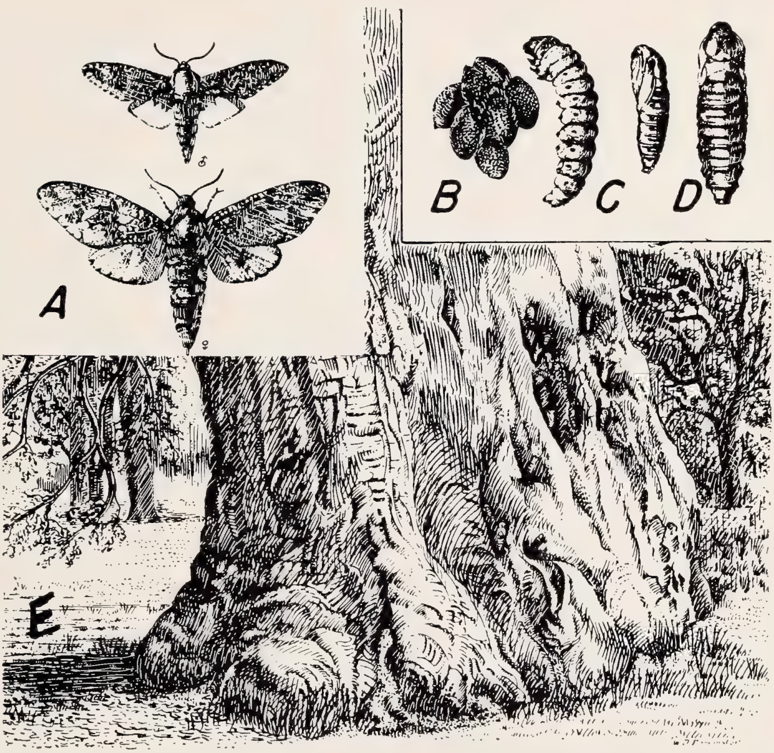

FIGURE 95.—The carpenter worm (*Prionoxystus robiniae*): *A*, Adult moths, × 0.5, male above; *B*, eggs, × 3; *C*, larva, × 0.5; *D*, pupae, × 0.5; *E*, borings in trunk of tree. (Drawings by Edmonston.)

The carpenter worm (*Prionoxystus robiniae* (Peck)) (fig. 95) is the most common representative of this group. It probably is the most destructive insect enemy of oaks in California, but also attacks poplars, cottonwood, ash, maple, willow, and other shade and fruit trees. It is distributed generally throughout the United States. The adult females are gray moths with a wing expanse of

2 to 3 inches. The males are smaller, with the front wings dark gray and the hind wings yellowish red lined with black. The mature larvae are about 2½ inches long, somewhat pinkish, with a dark head and with scattered hairs arising from small brown spots on the body. Eggs are laid in June and July, each female depositing from 200 to 300 in cracks and crevices or on the smooth bark of the host tree. The larvae mine in the sapwood and heartwood of trunk and limbs and cause injuries that show up later as defects in the lumber. Completion of the life cycle requires 3 years.

Another species, *Acossus populi* Wlkr., does similar work in poplars and cottonwood. *Givira lotta* B. & McD. works in the outer heavy bark at the base of ponderosa pines in Colorado.

CLEAR-WINGED MOTHS

Many species of clear-winged moths or pitch moths belonging to the family Aegeriidae work in the inner bark and bore into the wood of various forest trees. An exceptionally large number of them work in the wood of broadleaved trees and at times so riddle the interior that the limb or tree dies or is broken off by the wind, and the products derived from the wood show serious injuries. The adults of this group are very pretty clear-winged moths, resembling hornets. The caterpillars are naked or have only a few prominent hairs. So many species are seldom seen by the forester that no attempt will be made to list all of the western species here. **The alder borer** (*Thamnosphecia americana* (Beut.)) is sometimes found working in alder. **The locust clearwing** (*Paranthrene robiniae* Hy. Edw.) sometimes is very injurious to locust and poplar. **The cottonwood crown borer** (*Aegeria tibialis pacifica* (Hy. Edw.)) infests cottonwood, poplar, and willow, as does *Aegeria apiformis* (Clerck). *Ramosia mellinipennis* (Bdv.) attacks sycamore and oak in California.

HORNTAILS, OR WOOD WASPS

The horntails, or wood wasps (Siricidae), are injurious to the green, unseasoned, or moist wood of practically all western conifers. Frequently serious damage is done, especially to the wood of fire-killed trees. Sometimes redwood lumber is attacked and injured, even after it is cured and placed in storage yards.

The adult females are thick-waisted, cylindrical wasps, with two pairs of wings and a hornlike ovipositor, which resembles a stinger, at the rear of the abdomen. They are usually of metallic colors—dark blue, black, or marked with orange and red. The females alight on freshly felled injured or dying trees and with great dexterity insert their long flexible ovipositors deeply into the wood, often for an inch or more, and lay their eggs. Sometimes they are unable to extract their ovipositors from the wood and die in this position. The larvae are cylindrical and yellowish white, with a small spine at the posterior end of the body, and they sometimes hold their bodies in the shape of a shallow letter S. They are truly wood-eating in habit and work in the solid wood without any opening extending to the outside. As they feed they

make perfectly circular holes in the wood and pack their boring dust in the tunnels behind them. It takes one or two seasons for them to complete their development. Pupal cells are constructed near the surface of the wood, and when the adults mature, they cut round, clean-cut emergence holes to the surface through which to escape.

Prompt utilization of unseasoned wood exposed to attack by these insects is the best means of avoiding damage. Logs placed in mill ponds and frequently rolled will not suffer from attacks. Kiln-drying gives complete control, destroying the infesting larvae, and there is little danger of these insects attacking dry, finished lumber products.

The different species of horntails are very difficult to distinguish, and many of the species have not been named or satisfactorily separated. In many cases the males and the females of the same species have been given different names, since the sexes are markedly different in appearance. Only a few of the more common ones need be mentioned.

Urocerus californicus Nort. is the largest of the western species. The females are dangerous-looking wasps with black bodies and legs, yellow antennae, yellow bands on legs, patches of yellow on sides of head, and amber wings. They measure from 1¼ to 2 inches long, and the ovipositors are slightly shorter than the body. The males are smaller and have yellow bodies. The larvae infest true firs, Douglas-fir, and sometimes pine. *Urocerus flavicornis* F. is a somewhat smaller species, 1 to 1¼ inches long, and black, marked with yellow or red. It breeds in various coniferous trees, including the firs and pines.

Sirex californicus Ashm., a dark, metallic, blue-bodied species with buff-colored wings and black legs, is commonly found infesting pines in Pacific Coast States. *S. juvencus* L. is also metallic blue, but the legs are dark red or marked with yellow. It is found in pines, firs, and spruce throughout the West. **The western horntail** (*S. aerolatus* Cress.) is another metallic-blue species (fig. 96), with black legs and smoky wings. This species commonly attacks redwood, cypress, and cedars, but occasionally is found in pines and other conifers. *S. behrensii* Cress. is a smaller species, ⅝ inch in length, with head and thorax blue black and the apical segment of the abdomen reddish brown. The larvae infest ponderosa pine, sugar pine, and Douglas-fir, and have been found also in Monterey cypress.

Xeris spectrum (L.) is a very long, slim species, with an ovipositor at least as long as the body. The abdomen is wholly black and the legs are yellow. It has been found attacking lodgepole pine, Douglas-fir, and grand fir in the Pacific Coast States and Rocky Mountains. *X. morrisoni* (Cress.) is similar but has a reddish abdomen. It attacks Douglas-fir, white fir, lodgepole pine, and other conifers in the same regions.

BARK MAGGOTS

Peculiar defects in the lumber of certain coniferous trees, consisting of dark-brown or blackish resinous scars, with the wood

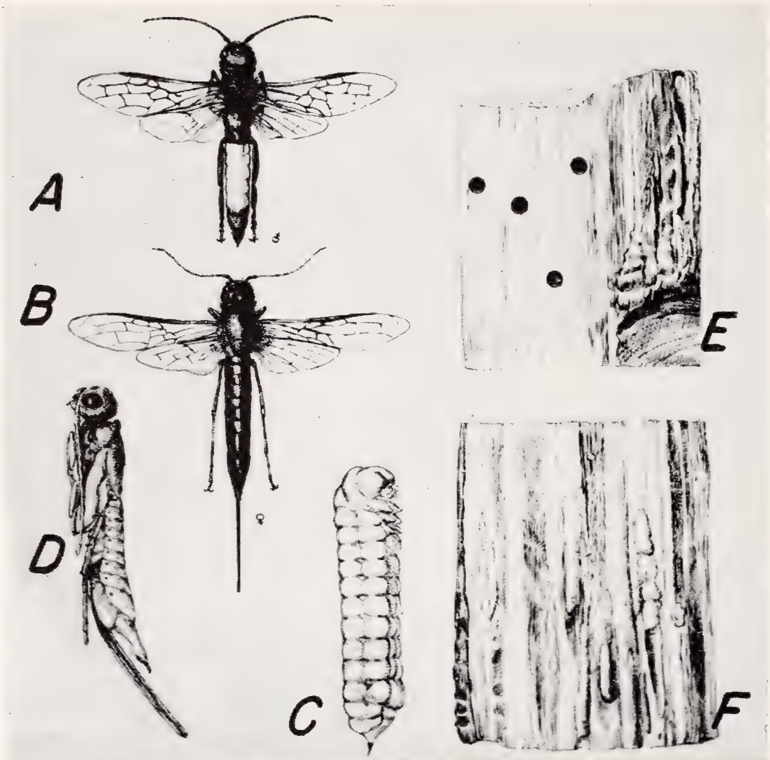

FIGURE 96.—The western horntail (*Sirex aerolatus*): *A*, Adult male, × 1.5; *B*, female, × 1.5; *C*, larva, × 3; *D*, pupa, × 3; *E*, exit holes; *F*, larval mines. (Edmonston.)

thickened and curled, are made by bark maggots of the genus *Cheilosia* (*20*). This type of defect is very prevalent in western hemlock growing in western Washington and Oregon at elevations below 1,800 feet and is called the "black check" of hemlock. These defects do not impair the wood for structural purposes but render a high percentage worthless for finishing wood, staves, or other special purposes.

The adults are small two-winged flies which lay their eggs on the bark of the trees, probably on the resin which exudes from feeding punctures made by the hemlock hylesinus. The maggots enter the bark, making a small wound, and feed on the sap and inner bark. The larvae, when full grown, are white maggots ¾ inch long, with the fore part of the body thickened and with a long, telescopic, protractile tail. Feeding continues for several years, then in the spring puparia are formed in the resin mass at the entrance to the wound, and the adult flies emerge in April and May.

Two species have been recognized as important in the West. **The hemlock bark maggot** (*Cheilosia alaskensis* Hunter) makes

FIGURE 97.—The hemlock bark maggot (*Cheilosia alaskensis*): *A*, Resin mass with exit hole made by adult fly; *B*, longitudinal section of similar mass, showing wound in inner bark and outer sapwood, pupal chamber and exit hole in outer pitch mass, and original beetle entrance connecting them; *C*, healing wound in inner bark beneath mass like that shown in *A*; *D*, wound; *E*, longitudinal section of wound; *F*, maggot; *G*, puparium; *H*, pupa; *I*, adult male; *J*, head of female: *K*. head of larva; *L*, antenna. *F*, *G*, *H*, *I*, and *J* × 2; *K* × 20; *L* × 45; (Burke).

the black check in western hemlock (fig. 97) and is distributed from Oregon to Alaska. *C. hoodiana* Bigot does similar work in white and grand fir in the same region and has also been reported from New Mexico. There are several other species whose habits are not fully known, which cause similar wounds in other western conifers.

INSECTS WORKING IN SEASONED OR DECAYING WOOD

POWDER-POST BEETLES

A group of beetles belonging to the families Ptinidae, Anobiidae, Bostrichidae, and Lyctidae are called powder-post beetles because the larvae burrow into hard, dry wood and reduce it to fine powder (*101*). There are hundreds of species in this group, many of which confine their attack to deadwood in the forest and are of

little economic importance. Most of them confine their attacks to the sapwood of the hardwoods, but a few species attack pine and Douglas-fir and occasionally do some damage. A few work in finished products and are extremely destructive on account of their ability to reinfest wood repeatedly until it is completely destroyed and to attack any exposed surfaces of furniture, flooring, and sills, and thus establish themselves in utilized wood products.

FIGURE 98.—Wood showing holes made by *Lyctus* beetles. (Snyder.)

The *Lyctus* beetles (*75, 143*) are probably the most dangerous and destructive members of this group (fig. 98). The adults are small, flat, slender, dark-brown beetles about 1/8 to 3/16 inch long. Eggs are laid in the pores of the wood, and the larvae bore only in the sapwood of various hardwoods, reducing it to a flourlike powder. The insects pass the winter as larvae. Pupation occurs in the spring, and the new adults appear early in the summer. In heated buildings development is hastened, and under such condi-

tions adults may appear much earlier. Small round holes in the wood from which fine powder exudes are a good indication of their presence.

Favorable conditions for attack are made when the sapwood of fine-quality hardwoods, especially of hickory, ash, and oak, is allowed to season for 2 or 3 years in undisturbed piles. Accumulations of old stock, refuse, and useless material greatly increase the hazard of infestation. Species of hardwood ordinarily not subject to the attack of these insects will, if piled with more favorable host species, share the damage of infestation. It is therefore, evident that proper methods of handling will do much to prevent these destructive pests from becoming established. Material should be inspected and rehandled annually, and all sapwood refuse, as well as stock showing signs of infestation, should be burned. Woods of different species should be piled separately and should be classified according to age of seasoning, in order that a constant turnover in yard stocks may be maintained by utilizing or disposing of the longest-seasoned stock first. The use of heartwood instead of sapwood, for piling sticks in the yard also helps to reduce the breeding ground. Kiln drying and steaming under pressure have produced gratifying control. An undesirable feature of the steam-pressure methods is that it is liable to lower the structural strength of the wood, and also there is danger of causing discoloration.

Great care needs to be taken in storage yards to prevent infestation from developing before the sapwood of hardwoods is treated with a filler, painted, or varnished and thus protected. Badly infested stocks of tool handles, oars, or building material should be burned. If lightly infested they can be treated by soaking in kerosene or by applying liberal doses of crude liquid orthodichlorobenzene, either undiluted or with as much as 8 parts of light fuel oil, or a 5-percent solution of pentachlorophenol in light fuel oil.

Where it is desired not to mar the finish of floors or furniture, these may be treated with a 9-to-1 mixture of turpentine and kerosene.

Stout's bostrichid (*Polycaon stouti* Lec.) is a large black beetle, about ¾ inch long with prominent mandibles. The larvae bore in the wood of various hardwoods such as oak, California laurel, madrone, alder, maple, and others in California and Oregon. There are several records of these large beetles having emerged from polished table tops where these native woods were used as a base for veneer. A smaller brown species, *Polycaon confertus* Lec., also mines in the wood of these and other broadleaved shade and fruit trees in California and Oregon, and is sometimes responsible for the extensive killing of twigs and branches.

The lead cable borer (*Scobicia declivis* (Lec.)) (*28*) feeds in all sorts of seasoned hardwood, including oak, maple, and California laurel. It has been particularly destructive in boring into alcohol or wine casks and into lead telephone cables. The adults are cylindrical dark-brown or black beetles about ¼ inch in length and have the head retracted under the thorax, giving them the appear-

ance of bark beetles. This species is common in California and Oregon.

The softwood powder-post beetle (*Hadrobregmus gibbicollis* (Lec.)) (*53*) probably is the most destructive of the native powder-post beetles found in the Pacific Coast States. The adults are elongate brown beetles about 1/5 inch in length, and the larvae are small white, curled grubs with three pairs of legs and an enlarged thorax. This species breeds in old, well-seasoned Douglas-fir timbers such as bridges and basement supports. Dry, unrotted, wide-grained sapwood is preferred. Attacks are most common in basement timbers and in other shady locations where a certain amount of moisture is present. Reinfestations continue year after year until the wood is reduced to a powder, leaving only an outer shell. On completing development the adults leave round holes nearly 1/8 inch in diameter on the surface of the wood. This beetle is not restricted to Douglas-fir, but has been found in limbs of redwood, bigleaf maple, and bitter cherry, and probably will attack other well-seasoned woods of suitable texture. It can be controlled by swabbing the wood with a 5 percent solution of pentachlorophenol in a light fuel oil, or by applying orthodichlorobenzene or other suitable wood penetrants.

CARPENTER ANTS

Large black ants belonging to the genus *Camponotus* are called carpenter ants because of their habit of tunneling into the wood of stumps, logs, dead standing trees, or the dead interior of living trees, and even into the framework of houses. There they excavate large cavities that they use for nests in which to rear their young. The wood is not eaten by the ants, but cast out to make room for the nests, causing little piles of wood fibers to collect below the entrance holes. Their excavations in wood are frequently so extensive as to seriously impair its structural value (fig. 99). In the Pacific Northwest carpenter ant damage greatly exceeds and to a large extent supplants that done by termites, the termite damage being much more prevalent farther south (*55*). These ants are general feeders, including in their fare both animal food and sweets, their preferred items of food appearing to be the caterpillars of certain lycaenid butterflies and the honey-dew excreted by aphids. They have even been known to shelter the aphid eggs in their nest during the winter and carry them out and place them on plants to develop in the spring.

These species differ from some of the other ant species in that the queen carpenter ant works alone in founding a colony. An interesting feature is that, from the time the queen builds her cell and begins to lay eggs until a brood of workers mature, no food is taken into the cell. This covers a period of about 10 days from the laying of the egg to the larval stage and perhaps 30 days more before the workers are mature and begin to carry in food. It is generally supposed that the queen carries enough food within her body to feed the growing workers, apparently by regurgitation.

Carpenter ants are difficult to control, and at times all remedies

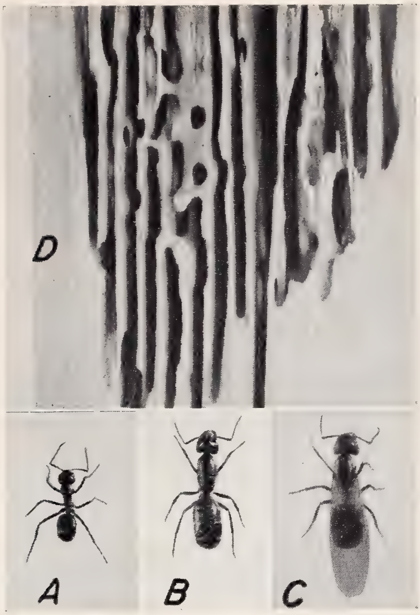

FIGURE 99.—Carpenter ants and their work: *A*, Worker; *B*, queen with wings shed; *C*, queen with wings folded; *D*, excavations in wood. Natural size. (Furniss.)

seem to fail. The first precaution is to prevent the ants from gaining access to foundation timbers. Where timbers are placed on solid foundations away from contact with the ground, the chance of carpenter ant attack is greatly minimized but not always prevented. The best preventive is to impregnate foundation timbers thoroughly with creosote.

After a piece of timber has become infested, the colonies of carpenter ants can be destroyed by dusting with 5-percent chlordane, 4-percent rotenone, 10-percent DDT, sodium fluoride or arsenical dust; or injecting liquid carbon disulfide or orthodichlorobenzene into the nests. The dusts are probably the most satisfactory, for the ants will track through them and carry them to all parts of the nests, whereas the liquids and gases are often blocked by the tortuous, partly frass-filled cavities. When house timbers become badly infested, it is often necessary to tear them out and replace them with timbers treated with creosote. All decaying wood in the vicinity of the buildings, such as old logs, etc., should be cleared away.

LARGE CARPENTER BEES

Certain species of large bees (Xylocopidae), resembling bumble bees, excavate large cylindrical tunnels in dry bark or wood in building their nests. Often they merely take over the galleries of other insects. Their tunnels, especially where several colonies of bees build nests close together, may weaken building

timbers and telephone poles; but usually their work is of no economic importance. Their work differs from that of the carpenter ants in that the burrows are partitioned into larval cells by chips of wood cemented together to form circular or spiral discs. Many species of these bees are found throughout the Western States, but they are particularly numerous in the Southwest.

TERMITES

The termites (*5, 97, 142, 144, 146, 147, 156*) (Isoptera) are a very destructive group of wood-boring insects that excavate large cavities in wood, and at times so mine the interior as to leave only a paper-thin shell. In the forest they are commonly found in the wood of felled trees, in snags killed by bark beetles or fire, and in stumps or other sections of dead or decaying wood. Insofar as they reduce forest debris they are beneficial, but they are exceedingly destructive when they turn their attention to fences, telephone poles, buildings, furniture, or other utilized cellulose products. The group as a whole finds its greatest development in the Tropics, and in the United States does the most serious damage in the warmer southern latitudes. A large number of species are found in the Southwest and southern California, but only a few extend their range into the Pacific Northwest and northern Rocky Mountain region.

Termites are dirty-white, soft-bodied insects that live in colonies in the wood or in the ground and expose themselves to the light only when in the mature winged adult form. Each colony is made up of several specialized forms, such as workers, soldiers, king, and queen or else secondary sexual forms (fig. 100). They look like soft, fleshy ants, but are distinguished from ants in having weakly sclerotized body parts, except the head; and the winged forms have four wings of quite similar size and shape, while the true ants have hind wings smaller than the forewings.

The social life of these insects is very interesting and complicated. Their excavations in wood are hollow, completely enclosed, more or less longitudinal cavities, in which some species deposit small, impressed pellets of excrement (*65*). The destructive subterranean form deposits liquid feces which make only characteristic spottings in their galleries.

The control of termites consists in isolating wood material from contact with the ground, or impregnating it with creosote or other termite-repellent materials. Very detailed methods of control have been devised, and it is recommended that the reader consult one of the publications devoted to the control of these insects (*97, 142, 144, 156*).

INSECTS INJURIOUS TO FOREST RANGE PLANTS

Grasses, herbage, and browse, which furnish feed to range animals, comprise a forest product sometimes of greater economic importance or value than the trees that grow on the area. These grazing plants may also suffer from insect attack and at times are so completely destroyed in certain localities that cattle and

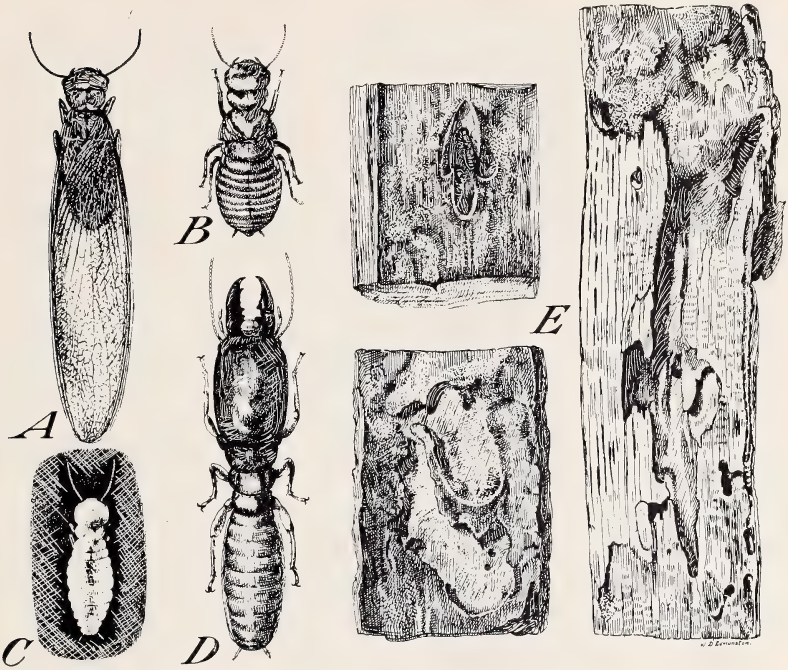

FIGURE 100.—One of the largest termites, *Zootermopsis angusticollis*, and examples of its work: *A*, Winged adult, × 1.5; *B*, second reproductive caste, × 1.5; *C*, worker, × 2; *D*, soldier, × 4; *E*, tunnels in wood. (Edmonston.)

sheep have to be moved to other ranges. Moreover, the damage to browse plants may carry over from year to year and reduce the available feed for several years. Fortunately there are comparatively few insects that cause serious damage to range plants.

The damage which grasshoppers may do to the grazing areas is well known to everyone, and the insects themselves are such common pests as to require no description. They are often particularly abundant in grassy meadows, where the females lay their eggs in the ground, usually during the fall of the year, and new broods emerge each spring to feed on all kinds of green and dry vegetable matter. The nonmigratory grasshoppers remain in a given locality and produce a new brood each year, under favorable conditions becoming excessively abundant and destructive. Others are migratory in habit and, after breeding to enormous numbers and having developed wings, travel across the country devouring every growing thing in their path.

Much attention has been given to the control of grasshoppers, and effective methods have been devised, the most satisfactory consisting in spreading poisoned baits broadcast over the breeding areas at about the time the young hoppers first come out and begin feeding. A good bait consists of a mixture of 1 pound of toxaphene, ½ pound of chlordane, or 2 ounces of aldrin to 25 pounds of bran or middlings, 3 bushels of sawdust, and enough

water to make a moist, crumbly mash. Aldrin dusts or sprays are highly effective.

Periodically armyworms, which are caterpillars of certain noctuid moths, appear in countless numbers and advance over grazing areas, devouring everything in their path. These also can be controlled to some extent by the application of poisoned baits similar to those used for grasshoppers, or by plowing trenches in front of the traveling army of worms and killing them in the trenches by dragging a log over them. Fortunately armyworm invasions on forest ranges are not of very frequent occurrence.

The Great Basin tent caterpillar (*Malacosoma fragilis* Stretch) (figs. 37, 101) (see p. 95) appears from time to time in the Great Basin area between the Rocky Mountains and the Cascades and defoliates bitterbrush (*Purshia tridentata*), which is a most important browse plant for sheep in this area. From 1928 to 1930 an invasion of this caterpillar swept over the range country of eastern Oregon and northern California and so seriously damaged the bitterbrush that it took several seasons for it to recover, and the carrying capacity of the ranges was greatly reduced. Epidemics could probably be controlled by aerial applications of DDT in fuel oil, provided a cost of $1 per acre is justified. After a few seasons of heavy feeding, often with serious injury to the older plants, outbreaks are brought under control by natural enemies.

The range caterpillar (*Hemileuca oliviae* Ckll.) (*160*) feeds on wild grasses and sometimes on cultivated crops, and at intervals of 10 or 12 years is a serious range pest from Colorado southward into Mexico. The adults are large moths with reddish, brown, or black bodies and buff or clay-colored wings. The caterpillars are yellow, gray, or black and have numerous coarse, poisonous spines.

The California tortoise-shell butterfly (*Nymphalis californica* (Bdv.) (fig. 102) is found throughout all the Western States and often appears in such numbers as to attract public attention. The caterpillars feed on different species of *Ceanothus*, and during severe epidemics other shrubs and trees may be attacked. The adults are medium-sized butterflies with a wing expanse of 2 to 2¼ inches. The wings are brown, with orange above, marked with black spots and black borders, with a single black spot and a marginal row of purple spots on the hind wings. The caterpillars are 1 to 1¼ inches in length, black with fine-branched spines on each segment, the middle row being bright yellow. The adults are in flight during midsummer.

The peppergrass beetle (*Galeruca externa* Say) is a black oval beetle about ¼ inch long, with a narrow yellow border on the elytra, which feeds on lupine in the Great Basin area. In 1934 it destroyed the lupines over hundreds of acres in eastern Oregon and also fed on the grasses.

The range crane fly (*Tipula simplex* Doane) (*128*) at intervals is very destructive to grasslands in California. It is also a serious pest of grains, barley, and alfalfa. The adults are grayish brown, long-legged flies about ½ to ¾ inch long. The females are wingless. The larvae, which are pale brown and somewhat roughened,

FIGURE 101.—Nest of the Great Basin tent caterpillar (*Malacosoma fragilis*) on defoliated bitterbrush.

live in small round holes in the ground, from which they emerge during the night or on dull days to feed on any green vegetation nearby. During mild or wet seasons vast areas of range land may be almost denuded. The spreading of poisoned-bran mash, such as is used for grasshoppers, is an effective control measure.

NATURAL CONTROL

The question is frequently asked, "Where did these destructive forest insects come from?" The answer is that most of them have been here as long as the forest trees on which they feed. Nearly all species of western forest insects, both injurious and beneficial, are native to these forests and are distributed throughout the range of their favorite host. Occasionally foreign pests

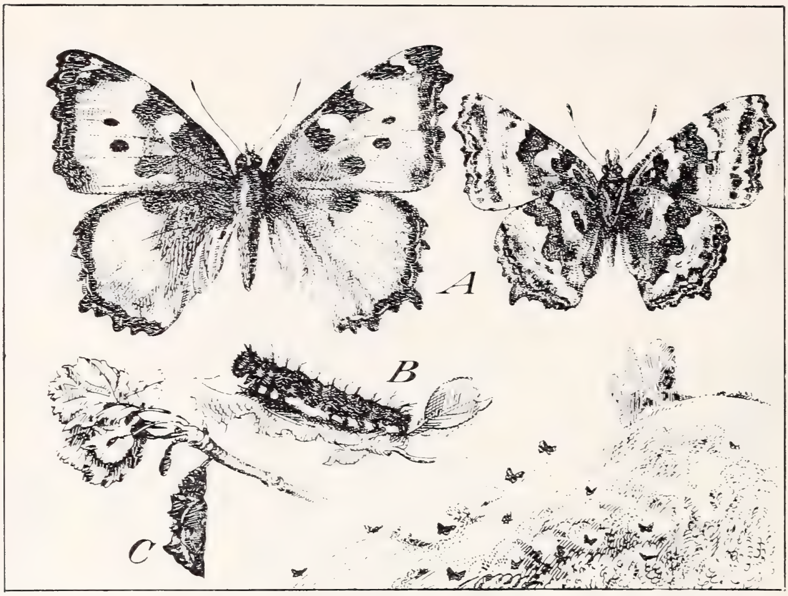

FIGURE 102.—The California tortoise-shell butterfly (*Nymphalis californica*): *A*, Adults; *B*, caterpillar; and *C*, pendulous chrysalids. About natural size. (Drawings by Edmonston.)

are introduced and become established where food and climatic conditions are favorable. So far, no introduced forest insects of major importance have found their way into the forests of the West. The destructive species were already here and widely established when the forests were first examined. Given favorable conditions for their increase, they can suddenly build up their numbers from the few parents which are normally present and develop epidemics.

In the insect world a constant struggle is going on for survival. On the one hand, the insects themselves are provided with potentialities for tremendous increase. Some females lay hundreds of eggs and some species produce many generations a year, so if all individuals survived the world would soon be overrun with the progeny. On the other hand, the insects must contend with many adverse conditions that serve to hold them in check. Weather conditions, food supply, prevalence of natural enemies, and many other environmental factors influence their abundance. Some of the more important of these factors will be considered.

CLIMATIC AND ENVIRONMENTAL INFLUENCES

Climatic factors, such as temperature, moisture, and weather conditions in general, have an important bearing on the abundance, activity, and distribution of insects.

TEMPERATURE

Insects as a rule have a very small range of temperatures (50°–95° F.) within which they are the most active; and the optimum for many of the Temperate Zone species appears to be about 77°. Temperatures either above or below this optimum range limit activity and extremes cause death (*119, 120*). Few insects can withstand temperatures above 120° and this makes possible the control of many species of bark- and wood-boring insects by raising the temperature of their environment to fatal heights. Low temperatures also are fatal. It has been found that larvae of the western pine beetle are killed when exposed to a temperature of –10° and extremely cold winters with air temperatures below –20° have proved fatal to a high percentage of this and other bark-beetle broods (*8, 94, 162*). Moreover, elevation and exposure modify temperature and limit the distribution of insect species, regulate their activity, and govern the number of generations per year.

MOISTURE

Moisture has an important bearing on insect abundance, both through its direct effect on the insects and indirectly through its influence upon the host. Some insects require very moist conditions under which to work to best advantage and are killed by dryness; others require very dry conditions and are killed by moisture. Moreover, moisture through precipitation has an important influence upon the growth and resistance of trees to bark-beetle attack; and periods of drought are frequently followed by serious consequences in supplying insects with an abundance of weakened host material (*11, 92*).

FOOD SUPPLY

The abundance or scarcity of the food supply is an important consideration in determining the distribution and successful development of insect progeny. Most of the insects that prey upon living forest trees are limited in their distribution to that of their favorite host, whereas those that feed on dying or dead trees are apt to be widely distributed throughout forest regions.

Insects, such as the defoliators, that attack healthy forest trees always have an abundant food supply at their disposal, and their numbers are controlled primarily by biological and climatic factors. On the other hand, a great many insects, such as most of the bark beetles, can develop in large numbers only when enough of their food material in a suitable condition for attack is available. Thus the development of certain destructive bark-beetle outbreaks is dependent largely on a supply of overmature or decadent trees, fire-weakened trees, slash, windfalls (*118*), snow-broken or lightning-struck trees, or trees weakened by drought, smelter smoke, disease, or other causes. Under favorable conditions, however, a few species of bark beetles can develop in epidemic numbers without such contributing factors.

In the virgin pine forests of the West, a high percentage of the trees are mature or decadent. They grow more slowly, and

resistance to beetle attack is lessened in other ways during periods of drought. Such conditions present a highly favorable field for bark-beetle activity, and the heavy losses that have been sustained in the pine regions during the past few years indicate very clearly that the bark beetles have not neglected this opportunity.

Trees that have been felled by wind or snow, injured in logging operations or in land clearing, or struck by lightning furnish favorable breeding places for many destructive bark and wood borers. Material of this kind is probably the natural habitat for many species that at times become excessively abundant and attack living trees. Many severe bark-beetle epidemics are known to have originated in areas of wind-blown timber.

SLASH

The debris left from the cutting of trees in the forest is a suitable and attractive breeding ground for a great many forest insects, some beneficial and some harmful (*61, 130, 155*). When slash is freshly produced, the dying inner bark is attractive to many species of bark beetles that commonly breed in standing trees. Usually these bark beetles select in the slash or stumps the type and size in which they normally breed. Thus the limb- and twig-feeding bark beetles go into the brush and smaller pieces of slash, trunk-breeding bark beetles go into the cull logs and butts, and those that normally work at the base of the tree attack the stumps. The abundance of the progeny depends a great deal on the moisture and temperature within the slash and the requirements of the different species of beetles. The red turpentine beetle, which breeds readily in pine stumps, frequently develops in such numbers as to do serious injury to adjacent forest trees. The trunk-breeding pine beetles rarely find suitable conditions in the cull logs and butts, and the progeny which they produce under such circumstances seldom cause any trouble in neighboring forests or to the reserve stand, especially where logging operations are continuous. The engraver and twig beetles, which breed in the smaller pieces of slash, frequently emerge in such enormous numbers as to kill patches of young trees and sometimes the tops of older trees.

The wood-boring species that breed in slash must be considered generally beneficial, in that they help to decompose the wood and reduce the slash with its accompanying fire hazard. They may become injurious, however, and in order to avoid or reduce a possible menace from slash-breeding insects special considerations in slash disposal are frequently necessary. When a logging operation is continuous, and a fresh supply of slash is furnished throughout the flight period, the emerging progeny is repeatedly absorbed in the slash and in the logs removed to the mill, and no special precautions need be taken. But if a cutting operation ceases or is intermittent, as in road and power-line developments, then some damage from slash-breeding insects may be expected and should be avoided if possible. Burning the slash is beneficial, provided the large limbs, cull logs, and stumps are included and the burning is done before the insects emerge. In many cases

this would mean that the burning would have to be done in midsummer or early in the fall, and this would present a fire hazard. Spreading the slash so that it will receive the direct rays of the sun will kill a high percentage of the insects in the more southern latitudes, where high temperatures can be attained in and under the bark in this way.

FIRE

Trees scorched or killed by forest fires are particularly attractive to many forest insects, which may be attracted from a radius of several miles (*122*). Subsequent insect damage augments the fire losses, as bark beetles often kill many trees that otherwise might have survived. Wood-boring species then enter the wood and so riddle the interior that within a few years it becomes valueless for lumber purposes (*96, 138*).

Forest fires do not help in destroying injurious bark beetles, as is sometimes supposed. Sometimes light burning has been advocated as a means of controlling bark beetles, but studies have shown that such fires are more apt to have the opposite effect. Destructive, tree-killing bark beetles never breed in and seldom inhabit the forest litter and duff, hence are seldom killed by light ground fires and can be killed in the trees only by a fire severe enough to kill the bark on the trunks. Such a fire obviously would do more harm than good.

NATURAL ENEMIES

Insects, like other living things, have natural enemies that prey upon them and tend to hold them in check. Three of the most important of these are birds, disease, and other insects. Small mammals, such as chipmunks, mice, and shrews, may be important predators of insects under certain conditions (*136*).

BIRDS

Many species of birds are insectivorous. Nuthatches, chickadees, creepers, warblers, kinglets, and many other species search for insects on tree trunks and foliage, while woodpeckers dig through the bark and feed on larvae of bark beetles and wood borers. Counts have shown that fully 75 percent of the western pine beetle population in patches of pine bark worked over by woodpeckers have been destroyed by these industrious workers. But not all birds are beneficial in this respect. Some are as destructive to beneficial insects as to the harmful species, and their feeding has ultimately little effect in reducing the injurious forms.

DISEASE

Insects are subject to many fatal diseases, which sometimes help to suppress an outbreak of some harmful pest. These diseases are produced by many different micro-organisms, including bacteria, fungi, and the causes of polyhedral bodies. Few have been adequately studied. One of the most common examples is a wilt disease that spreads rapidly through outbreaks of various

caterpillars. The caterpillars suddenly sicken and die and are seen hanging from leaves and twigs blackened and shriveled.

BENEFICIAL INSECTS

Many species of insects belonging to different orders and families are distinctly beneficial in that they devote their lives to preying upon certain harmful species (*81*). These beneficial forms may be divided into two large groups: (1) The parasites, which live in, on, or with some particular host and gradually consume it, and (2) the predators, which feed externally and devour their prey. The line of demarcation between a parasite and a predator is not a rigid one, since both live at the expense of their host. A parasite is usually considered as one capable of completing its life history in or upon the body of one host, whereas a predator feeds on a succession of individuals. Often both the immature and adult forms of predaceous insects feed directly on all stages of their insect hosts.

Most of the parasites belong to two or three families of wasps (Hymenoptera) and one family of flies (Diptera). The wasps frequently have long ovipositors with which they deposit their eggs, often within the body of their insect hosts. Here the egg hatches and the young parasite grows to maturity, feeding on and finally killing its victim. Parasitic flies lay their eggs on the surface of the host, and the maggots burrow within. Native forest insects have many parasitic enemies. Unfortunately, even the beneficial insects are not immune from attacks of other parasites, called hyperparasites. Hyperparasitism is occasionally carried to the third and fourth degrees, making parasitism an extremely complex relationship.

The most active predaceous insects are beetles belonging to the families Cleridae, Ostomatidae, Carabidae, and Coccinellidae; several families of flies (Diptera); lacewing flies of the family Chrysopidae; and several families of true bugs belonging to the order Hemiptera.

The larvae of some of the roundheaded borers are very voracious bark feeders and are often unwittingly beneficial in that they devour the inner bark so rapidly as to rob the bark beetles of their food. This is a case of competition between two species of insects, one of which is capable of killing trees and the other harmless in this respect, with the harmless species depriving the destructive one of necessary food material.

Under normal conditions, the operation of these physical, nutritional, and biological forces counteracts the enormous reproductive capacity of the insects and tends to keep the destructive and beneficial insects more or less in balance. The few harmful individuals which escape their enemies live and feed on their hosts without doing conspicuous injury. The defoliating insects feed on a few leaves or needles, but the damage is so small as to escape notice. The bark beetles kill an occasional tree or breed in down logs and broken tops. The aggregate damage is negligible, and the annual growth which the trees acquire exceeds the drain, so that there is a net accretion of volume in the stand. Insect

infestations which continue under these conditions are called endemic. This is the normal condition in nature and it is a hopeless and unwise undertaking to try to exterminate native insects under such conditions. The result of an effort in this direction would be more likely to disrupt the delicate balance than to accomplish the objective.

Under certain conditions, the natural balance may be broken by any one of a number of factors. For example, the beneficial insects or other enemies of harmful species may become reduced in numbers; the resistance of the trees may be lowered through drought, fire, or stagnation; large quantities of slash or other breeding material may become available; or climatic factors may become especially favorable. Under any such condition the injurious species will breed rapidly and a sudden destructive outbreak will soon develop. Within a few seasons a large proportion of a timber stand may be killed by bark beetles. Such epidemics may continue for years and spread over large areas. Defoliators may suddenly appear within an area and, after destroying the foliage of valuable timber over large acreages, disappear with equal suddenness. Many factors come into play in bringing about these sudden changes, and it is often difficult to isolate the responsible causes. Outbreaks of such a character are called epidemic infestations and require immediate attention and drastic control.

CONTROL OF INJURIOUS FOREST INSECTS

The objective in forest-insect control, in areas not under intensive management, is to prevent or suppress epidemic outbreaks of injurious insects and to prevent their spread. As has just been indicated, it is best not to disturb normal infestations of native insects, for there is small hope of exterminating them, and the complicated factors that hold the species in balance may be unfortunately disrupted. Control of native pests is therefore confined to the preventing of threatened outbreaks and the suppression of those that have attained some proportions. With defoliators, the object is to hold down the injury to as low a point as possible until natural factors suppress the epidemic. In bark-beetle control the objective is to prevent or suppress the development of a large beetle population, at the same time giving every encouragement to the natural control agencies, so that the natural balance may be restored (*62*).

The control of forest insects, scattered as they are over vast forest areas, may seem an insuperable undertaking, and yet certain methods are available that make this not so hopeless a task as it might appear. Control problems may be approached in at least three different ways: (1) Through such direct remedial methods as destroying the insects by burning, drowning, or poisoning; (2) by silvicultural methods that modify the physical or nutritional forest conditions so as to change temperature, moisture, or food supply; and (3) by biological methods that alter conditions so as to increase the numbers of natural parasitic

or predaceous enemies. Though these are distinct methods of approach, it is often necessary to utilize more than one of them in the solution of some forest-insect problems.

Forest-insect control in the Western States is at present largely a matter of protecting mature timber stands from the ravages of insects by applying direct remedial control measures. But as mature timber stands are cut and brought under management, there will be more and more opportunity to apply silvicultural measures in the solution of forest-insect problems. The application of biological methods will depend largely upon what is discovered through further research work as to the various interrelationships of the insects concerned.

The control of introduced or foreign pests presents quite different problems. In the first place, every effort is made to prevent their introduction into this country through rigid quarantine inspections at all ports of entry. Such pests as escape detection and become established in the country are hedged about with domestic quarantines for the prevention of their further spread, while every effort is made to exterminate them before they have become so firmly entrenched as to make such efforts impractical. If these efforts fail, a search is made in their native homes for the specific parasites and predators that normally hold the pests in check there, and these are introduced and their establishment attempted in this country. Work of this sort has been highly successful in controlling many foreign pests that have been inadvertently introduced.

SILVICULTURAL CONTROL

When timber stands are brought under management, it becomes possible so to regulate conditions as to make forests less vulnerable to insect attack; or if insect damage does occur, to salvage the timber without undue loss. The underlying aim is to maintain a biological balance throughout the period of rotation. This task is hardly as simple as it sounds and cannot be accomplished without a thorough understanding of all the factors contributing to insect abundance and the resistance of forest stands. The possibilities in this direction have not as yet been fully investigated, and there is still much to be learned about the management of western forest types before thoroughly sound methods of procedure can be recommended with complete assurance of success (*36, 93*).

It is apparent, however, that this field of silvicultural control offers almost unlimited possibilities. In the older forests much can be done to lessen insect damage by avoiding injury to the trees from forest fires and other weakening influences; by keeping forests in a healthful condition through disposal of windfalls, slash, and other insect-breeding places; and by selective cutting operations to remove the trees most susceptible to insect attack, and through these cuttings to regulate forest composition and density. In new plantations consideration should be given to the selection of the site and the planting of species and varieties of

trees best adapted to it, to their proper spacing, and to the regulation of drainage, temperature conditions, and stand density. Mixed stands are also less susceptible to serious injury than pure stands. These are just a few of the possibilities that suggest themselves in which insect activity can be modified through silvicultural practices.

In the overmature virgin forests of ponderosa pine, bark beetles are not indiscriminate in their attacks but make a selection of certain trees or groups of trees scattered through the stand (*133*). A study of the types of trees selected has shown that in general the more slowly growing trees, the codominants and intermediates in the stand, and the older age classes are selected in preference to the thrifty, dominant, young trees (*91*). It also has been found that trees currently in poor health are of highest risk to western pine beetle attack (*141*) and that beetle control can be obtained over a period of at least 12 years through sanitation-salvage logging, in which the high-risk trees, constituting usually from 15 to 25 percent of the stand, are removed and utilized. Instead of cutting heavily on small logging units, forest managers are favoring a light selective system whereby large areas will be opened up so that insect-killed and high-risk trees can be quickly harvested and stands improved in both growth and insect resistance (*126, 127*).

Under management, the age at which certain stands become susceptible to beetle attack will necessarily be taken into consideration, and a cutting rotation adopted that will permit the timber crop to be harvested before the beetle hazard becomes too great. Lodgepole pine is a good example of a tree whose short life is largely a result of periodic, devastating outbreaks of the mountain pine beetle.

In some cases stand composition and density will have to be regulated to avoid serious damage from insect attack. Pure stands—those composed of a single tree species—are particularly susceptible to disastrous outbreaks. For instance, outbreaks of the hemlock looper have been especially destructive only in stands composed of a high percentage of hemlock. Where a heavy mixture of other species occurs the infestation soon thins out and loses its destructive power. Attacks of the spruce budworm also have been most destructive in stands composed of a high percentage of true firs and Douglas-fir. It is particularly important that cuttings, in stands that normally grow as mixed types, should not favor the leaving of a single species. This is not so important in stands that normally occur in nature as pure types, for in such stands there is usually a natural balance between the tree species, the vegetative ground cover, and the insects associated in this type of forest. Stand density has an important bearing on temperature and moisture conditions and often must be regulated so as to improve growth rates and discourage the attacks of certain insects.

Many of these problems of silvicultural control become increasingly important when new plantations are established. Sites must be selected that are adapted to the growing of trees, or growth

will be so poor and the trees so weak that insects will have a fertile field for their activities. Here, too, there is the opportunity to select varieties of trees not only adapted to the particular site but also insect-resistant or capable of making such rapid growth as to overcome any set-backs from insect attack. Drainage, the mixture of species, and the spacing of the trees also must be given special consideration.

BIOLOGICAL CONTROL

As has been previously mentioned, parasitic and predaceous insect enemies and insectivorous birds and mammals are often of great value in holding destructive forest insects in check. To increase the effectiveness of these natural control agencies through artificial means offers hopeful possibilities, but is beset with many difficulties (*62*).

If the native insects already have a full complement of natural enemies, an effort can be made to create favorable conditions for the multiplication of these beneficial agencies. Direct control methods, such as burning or sun-curing, can be modified so that the beneficial insects will not be destroyed in as large numbers as the harmful species. Sometimes only a slight change in this direction will give the beneficial insects the upper hand, and they will quickly bring an epidemic back to normal balance. To increase these native insect enemies through artificial propagation presents seemingly insurmountable difficulties with little hope of any lasting benefit.

Another possibility is the introduction of a new parasitic or predaceous enemy. To do this, it is first necessary to find an insect not already present within the infested area that will prey upon the harmful species. Even though such an enemy may be found, there are many complex factors that will influence the success of the introduction and its ultimate effectiveness. The life history of the new enemy must synchronize with that of its host if it is to be on hand at the proper time for attack. If a parasite has more generations annually than the host, other insects must be present for it to attack at other periods during the season. The parasite must be capable of wide distribution and have a greater reproductive capacity than that of its host. Moreover, its ability to adapt itself to the change in climatic conditions in its new environment may be an important factor in determining its ability to succeed. So far, no introduction of a foreign parasite or predator has been outstandingly successful in the control of any of our native forest insects.

The introduction of parasites and predators has been confined largely to cases where injurious insects have been accidentally imported into new regions while their natural enemies have been left behind. Under such conditions the introduction of parasites from the original home of the pest have, in several instances, been entirely successful, although the continuation of artificial control has frequently been necessary. In only a few instances

have introduced beneficial insects been able to control destructive epidemics completely without other assistance.

Since the application of biological control measures often presents almost insuperable difficulties, a thorough knowledge of all associated insects is of vital importance, in order that the more direct control methods may be applied so as to take full advantage of any aid from parasites and predators.

ARTIFICIAL OR REMEDIAL CONTROL

When nature fails to keep an injurious insect in check, and valuable forest crops are threatened with destruction or serious injury, direct remedial or artificial control measures are called for. These consist in such mechanical methods as the application of insecticides, as in spraying, dusting, fumigating, or baiting; felling or burning infested trees; or the use of trap trees or solar heat. In brief, these artificial control measures are employed to destroy the harmful insects directly in one way or another.

The control measures applicable to the control of cone and seed insects, root-feeding nursery pests, terminal or twig insects, and insects injurious to forest products have already been considered in connection with the discussion of these special groups. The control of defoliating insects and bark beetles affecting mature forest trees has been given special attention in western forests, and, since specialized methods have been developed, these will be given detailed consideration.

CONTROL OF DEFOLIATING INSECTS

Defoliating insects can be controlled with chemical poisons. Application of insecticides to forest trees over extensive areas is often impractical with ground equipment. It did not become feasible until airplane dusting and spraying were developed. This method of application, together with DDT and the other new potent insecticides developed during World War II, has so revolutionized the control of forest defoliators that only brief mention can be made of some of the older methods.

MATERIALS

Insecticides commonly have been divided into two groups depending on how they reached the insects: (1) Stomach poisons, and (2) contact poisons. To these now must be added a third group which act both as stomach poisons and contact insecticides.

The most useful stomach poisons are various arsenical compounds such as lead arsenate and calcium arsenate. Lead arsenate and calcium arsenate are not only toxic to the insects but contain comparatively little free arsenic and hence are not harmful to the foliage of many trees when used with discretion. Calcium arsenate is the cheaper of the two, but lead arsenate is somewhat more effective and less injurious. A spreader is usually added to the liquid sprays in order to make them spread evenly over the surface of the foliage and to adhere well. Fish-oil soap, linseed oil, glucose, resin stickers, and similar substances are frequently used for this purpose (*134*).

The stomach-poison spray most frequently used for the control of leaf-chewing defoliators consists of the following: Lead arsenate, $1\frac{1}{4}$ to $1\frac{1}{2}$ pints of the paste or 3 to 5 pounds of the powder, fish-oil soap 5 to 6 pounds; and water to make 100 gallons.

Contact insecticides are used against small sucking insects such as the aphids, scales, and bugs, and sometimes against small caterpillars and leaf miners, and are applied in the form of liquid sprays or dusts so as to come in direct contact with the insects. These poisons kill the insects by entering the respiratory system, or by penetrating through the thin body membranes, or they may destroy them by plugging their breathing tubes, paralyzing the nerve centers, or actually burning the insects through the caustic properties of the chemicals. The young insects are much more easily killed by such treatment than the older forms, which often become resistant.

There are a large number of contact sprays and dusts, each with certain advantages and special fields of usefulness. Only a few will be mentioned here, since the contact sprays, while very useful in the control of shade-tree pests, have not as yet been used in the forests of the West.

One of the most useful contact sprays in the control of aphids and other soft-bodied insects contains 1 pint of 40-percent nicotine sulfate and 5 pounds of fish-oil soap in water to make 100 gallons.

Miscible oils have come into prominence in recent years for use on shade and orchard trees, and are useful in nurseries and plantations against such forest pests as the spruce gall aphid, the green spruce aphid, and various scales. These oils are sold under various names, and they vary somewhat in strength. The winter oils are used as dormant sprays and will injure foliage if applied when the trees are in leaf. Summer oils, which can be applied to the foliage without injury, are also available. Instructions as to dilution of the oils come with the product. Fish-oil soap is often used as a spreader.

Lime-sulfur is a very effective and inexpensive spray material which is used in the control of the armored scales. It is applied during the winter or early in the spring as a dormant spray. The concentrated preparation should have a density of about 30° Baumé and should be diluted with 8 parts of water.

DDT, benzene hexachloride, and chlordane, have largely replaced some of the older insecticides. Each of these new insecticides is especially potent against certain groups of insects, yet ineffective against others; so no one insecticide can be used for all purposes. DDT, for instance, is outstandingly effective against most caterpillars and sawflies, which constitute the bulk of the important western forest defoliators, but is ineffective against aphids and mites.

Technical DDT is a gray or cream-colored lumpy powder, with which various insecticidal formulations are prepared. For control of forest defoliators four general types of preparations may be used: (1) Dusts, in which DDT is mixed with a dry carrier; (2) wettable powders, which are mixed with water to form suspen-

sions for spraying; (3) emulsifiable concentrates, which are mixed with water to form emulsions for spraying; and (4) oil solutions, which are applied directly as sprays.

For use on ornamental shrubs and trees in parks, and in other situations where applications can be made from the ground, with hand or power sprayers, dusts containing 3 to 5 percent of DDT and sprays prepared from 50-percent wettable powders at the rate of 2 pounds and 25-percent wettable powders at 4 pounds per 100 gallons of water, and emulsions at 0.8 to 8 pounds of DDT per 100 gallons are suitable.

For airplane spraying a 12-percent DDT oil solution is most frequently used. This is made by dissolving 1 pound of technical DDT in 1 gallon of a mixture of 15 parts (by volume) of benzene, xylene, or methylated naphthalene and 85 parts of Diesel oil or No. 2 fuel oil. This solution is applied at the rate of ½ to 1 gallon, or ½ to 1 pound of DDT, per acre. When applied from the ground by power sprayer, the solvents injure foliage, but in the mist developed by airplane or helicopter sprayers the oil evaporates rapidly and very little foliage burning results from the low dosages applied.

So many new insecticides and combinations of ingredients are now used for specific purposes that, if special problems arise requiring the use of insecticides, it is best to consult an entomologist.

POWER SPRAYING

Power sprayers mounted on motor trucks may be used in the control of park- and shade-tree defoliators, but in forests their use is limited to areas along roads or to camp sites and resorts where it is possible to transport this heavy equipment. Because of the height of forest trees, high-power spraying pumps are a necessity; but even with the largest equipment so far developed it is not possible to reach a height of much over 90 feet, nor is it feasible to reach out with spray hose more than 5,000 feet from roadways (fig. 103). Mist blowers and fog machines have been developed for applying light deposits of DDT and other contact sprays to orchard and shade trees, but thus far their use in forest-tree spraying has been limited.

AIRPLANE SPRAYING

Since 1926 (*52*) the airplane (fig. 104) has come into use for spraying forest areas, and the helicopter is now being developed for special work of this type.

In the early work of treating forest areas from the air, dry dusts, principally calcium arsenate, were used. Airplanes were equipped with hoppers carrying 1,000 pounds of dust which was applied in 150-foot swaths at the rate of 20 pounds per acre by an airplane flying about 40 feet above the tree tops. Costs ranged from $3 to $6 per acre. It was extremely difficult to get a uniform coverage with dry dust, because it drifted badly and did not adhere well to foliage. Although several large forest areas were treated in this manner, the results were only moderately successful (*152*).

FIGURE 103.—With a long hose it is possible to reach distances of 1,500 to 5,000 feet from the spray pump.

With the development of DDT new progress in airplane spraying for control of forest defoliators became possible, for this insecticide has many characteristics that make it ideally suited to this work. Incredibly small amounts—from 1/4 to 1 pound per acre—are sufficient for effective control. DDT can be dissolved in fuel oil, which flows freely and uniformly from spray jets without clogging. Small quantities—1 gallon of spray per acre—are sufficient to give residual deposits that are lethal to crawling insects for many weeks. If dosages have been kept below 1 pound per acre, no deleterious effects on birds, fish, and other wildlife have been evident.

FIGURE 104.—Refilling an insecticide tank on a Stearman plane.

The largest airplane spraying project ever conducted in the United States up to 1947 was undertaken in northern Idaho, small areas in northeastern Oregon, and eastern Washington, to control an outbreak of the Douglas-fir tussock moth. From May 22 to July 2, 1947, 11 planes made 2,120 runs and deposited 390,878 gallons of DDT spray on 413,469 acres of forest land (fig. 105). The spray contained 1 pound of DDT in a solvent with light fuel oil to make 1 gallon of spray for each acre treated. The spraying was phenomenally successful in killing all tussock moth caterpillars on the treated area.

The type of aircraft best suited for forest spraying and the equipment needed for carrying and releasing sprays of proper droplet size at the desired rate have been subjects of much investigative and engineering work. Developments have been so rapid and are so specialized that they cannot be adequately covered here. Most of the forest spraying has been done by contractors who have special equipment and pilots trained and experienced in this type of work.

BARK-BEETLE CONTROL

A tree in which bark beetles have successfully established themselves cannot be saved, and the best that can be done is to destroy the infesting insects before they are able to emerge and attack other trees (*80*). Bark-beetle broods can be destroyed by several methods of artificial control (*86*), the method and time of application varying for different species and different regions. Though bark-beetle outbreaks can be reduced, these insects cannot be exterminated, so control measures must not be considered as a panacea or cure for all time. The results of a successful bark-

FIGURE 105.—Trimotor spray plane in action on the 1947 tussock moth control project in Idaho.

beetle-control project may last for years or they may be of extremely short duration.

In justifying the application of measures for the control of bark beetles, such factors as the value and merchantability of the timber, the destruction of the forest cover in its relation to watershed protection, the creation of fire hazards, and the danger of the epidemic spreading into more valuable stands of timber must be considered. The proper evaluation of these factors, balanced against the cost of the operation, will determine the economic justification of the project. However, it is difficult to foresee the extent of the probable damage or the course the epidemic may take if no control is undertaken, and conclusions as to the success of a bark-beetle project can only be deduced on the basis of an estimate of what would have happened had no control work been undertaken. Control measures applied during the decline of an outbreak often tend to place an inflated value on the results obtained. On the other hand, control undertaken during the time an outbreak is building to an epidemic may show little reduction in damage and give the appearance of failure. The best that can be done is to compare the trend of the epidemic on the treated area subsequent to control with that on a similar neighboring area where no work was done.

To protect valuable forest areas from bark-beetle outbreaks the following steps should be taken:

(1) A general reconnaissance or detection survey of valuable forest types subject to bark beetle epidemics should be made each year to detect the beginning of any outbreak. If an outbreak is indicated, a decision should be reached by the owners or those responsible for forest protection as to whether timber values in or adjacent to the site of a detected outbreak warrant the probable expense of a control operation. If so—

(2) An extensive bark-beetle survey should be undertaken, usually under the supervision of a competent forest entomologist, to determine (*a*) the trend of the outbreak and the possibilities of natural control; (*b*) the area involved in the infestation and threatened by it ; (*c*) what areas must be included in the control program; (*d*) the number of trees that will require treatment, and the area that must be covered in the first season; and (*e*) the probable cost and results to be expected. In the light of the information furnished by such a survey, a decision can be reached as to the need and justification for applying control measures, and whether or not the cooperation of all affected owners can be obtained and the work adequately financed. If control work is decided upon, then—

(3) A control campaign should be outlined and prompt and thorough control measures should be applied to all units showing epidemic trend within the project area. This should be followed by treatment of such outlying areas as may jeopardize results in the cleaned units.

(4) A maintenance control program should be continued until a natural balance has been restored.

DETECTION OF BARK-BEETLE OUTBREAKS

If forests are to be protected from serious damage or destruction by bark beetles, incipient outbreaks must be promptly discovered and reported. If such a system is consistently carried out, it will greatly reduce the ultimate cost of protection and prevent the building up of disastrous and uncontrollable infestations.

The first reporting of outbreaks devolves upon the timber owners, the State or Federal forest rangers, or others who are primarily responsible for the protection of forests. Such work is analogous to that of the forest-fire detection system.

This detection work should be so planned that all valuable forest types subject to bark-beetle outbreaks are given some measure of inspection for insects each year. This work does not need to be intensive, but at least it should disclose whether trees are dying through any forest tract, and, if so, the probable cause of death and the extent of the trouble.

If trees are observed to be dying, either singly or in groups, they should be examined and the cause of the trouble determined. If there is no evidence of recent forest fires, insects may be suspected. A closer examination of foliage, twigs, or bark should show what primary insect is involved. The keys and accompanying

discussions in this manual should be helpful in making this diagnosis. If the cause of death cannot be determined, an expert should be called in or samples of the work and the insects present should be sent to an entomologist for study. Samples taken from the middle height of the stem are more likely to include the primary destructive bark beetles than those taken near the ground or in the tops, where secondary insects are often most abundant.

The extent of the damage can be determined by a red-top survey or by strip counts made along roads or trails. The methods to be discussed in the next section are applicable to this preliminary work, but the field work need be only in sufficient detail to give a rough approximation of the location, extent, and intensity of the infestation.

The prompt reporting of the first signs of a bark-beetle outbreak will greatly reduce the ultimate cost of suppression. On most national forests the rangers are required to make at least one annual reconnaissance of their districts and report insect infestations. In this way bark-beetle outbreaks are promptly brought to the attention of the forest officers and a decision can be made as to whether a more extensive survey or immediate control operations are required.

EXTENSIVE BARK-BEETLE SURVEYS

After an infestation has been reported by the men on the ground, there is usually need for a more complete survey to determine the intensity, size, and character of the infestation, whether or not control operations are justified, and how large an area must be included to make such work effective. This extensive survey is usually made by experts in forest-insect control who have had experience in estimating bark-beetle losses and planning control campaigns (*18*).

The importance of obtaining all possible information before control measures are started can hardly be overemphasized. Without this information the need and feasibility of control and the magnitude and probable cost of the proposed operation cannot be determined. No project should be undertaken without fairly accurate knowledge of conditions in all surrounding watersheds.

One of the first things to be done is to determine the trend of the infestation—whether normal, increasing, or decreasing—and the possibility that natural control factors will soon become operative. This is done by a thorough study of brood conditions and a comparison of past with current losses. Control measures need not be applied to normal or rapidly declining infestations.

The next step is to determine what areas must be included in the control program, the number of trees that will require treatment, and the probable cost of the work.

The methods to be used in such work will depend on the character of the country, the size of the area involved, the degree of accuracy desired in the results, and the time and money available. The simplest and least expensive type of survey is made by viewing the country from lookout points and making counts

along roads. Sample strips run at intervals back and forth across infested areas permit a very comprehensive estimate of the amount and distribution of infestation, and where time and money are available these unquestionably furnish the most satisfactory basis of estimates. The cruising of sample plots has its place as a supplement to topographic viewing, and with small units it is often possible actually to survey a rather large portion of the area in this way. Where large areas of diverse topography include a number of different forest types, several methods may be used. In fact, every source of information should be utilized in arriving at the final estimate.

The Topographic Method

The topographic method, or red-top survey, is particularly well adapted to estimating bark-beetle losses over large forested areas of rough topography, where a large part of the forest can be viewed from open valleys, ridges, or lookout points. It is the cheapest and quickest method but is subject to a high degree of error unless supplemented by intensive examinations of sample plots or strips.

In using this method, the estimator, equipped with binoculars and a topographic map of the area, travels through the area visiting all of the ridges, valleys, or lookout points that can be found. At each selected point the opposite slopes and visible areas are viewed, the red, sorrel, or fading trees counted, and an estimate placed on the map as to the total number of dying or dead trees per acre. Then strips or plots are actually cruised and a ratio determined between the number viewed and the total number actually found. Also, the proportion of newly infested and abandoned trees, all of which have been counted in the general survey, is determined. The total estimate is then corrected by these ratios.

The Sample-Strip Method

The sample-strip method is adapted to estimating bark-beetle losses on flat or gently rolling areas where viewing from a distance is impossible. It is also a more efficient and accurate method and can be used by inexperienced estimators with a fair degree of accuracy. In order to cover any large area, however, a great many strips must be run, which makes the method more laborious and consequently more time-consuming and expensive.

In using this method, the observer travels through the forest along some routes of known position and length, such as a forest road or trail, but preferably along a section line or compass line, so as to obtain an impartial cross section of the area uninfluenced by the special forest types which might be encountered along ridges or canyon bottoms. Distances are determined by pacing, or using the known distances between fixed points, such as section corners or topographic features located on accurate maps. Without attempting to blaze or mark the trees, the numbers of fading,

sorrel, or red-top trees are counted within a specified distance on either side of the line of travel.

The width of the strip will depend on the density of the forest stand, and should be so chosen that the outer edges will correspond approximately with the average limit of vision within the stand. For open ponderosa pine stands a 10-chain strip (330 feet on each side of the center line) has been found generally satisfactory, but in the heavier stands this often needs to be reduced to an 8-, 5-, or even a 4-chain strip. In lodgepole and western white pine stands, red-top surveys usually are limited to 5-, 4-, 2-, and even 1-chain strips. However, in these types extensive surveys are usually conducted in the fall of the year to determine the number of new attacks, and the old loss represented by the red-top trees is ignored. Since the newly attacked trees are not discolored and can be found only by sighting the pitch tubes, very narrow strips are necessary, and a 1-chain strip (33 feet on each side of the compass line) has been adopted as standard for this work in the northern Rocky Mountain region.

When a red-top strip count includes several ages of infested and recently abandoned trees, it is necessary to examine a representative series of trees, either on a sample strip or on a sample plot, to determine the proportion of the different classes of insect attack and years of infestation which may be represented. A limited amount of intensive work is also necessary to determine the average diameters, heights, and volumes represented by the infested trees. The number of trees counted on the strips multiplied by the number of times the acreage of the strip would be contained in the acreage of the entire area will give the approximate number of trees for the entire unit.

No fixed rule can be given as to the portion of an infested area that should be covered during an extensive insect survey to obtain a reasonable degree of accuracy. The exactness of the survey will depend on the time and money available and the value of the timber stand under examination. Small units of valuable timber should be covered with a greater refinement of methods and a higher degree of accuracy than an extensive area of heavily infested lodgepole pine. Ordinarily 5 percent of an area should give a reasonably good estimate for control purposes, and on large areas a 1-percent sample is often sufficient.

WHEN CONTROL MEASURES ARE ADVISABLE

When the natural balance in a forest is disturbed and an outbreak of bark beetles threatens to destroy a large number of valuable trees, the application of direct control measures (*39*) is advisable provided effective methods are available and the value of the timber that can be protected will justify the expense of the work. Control measures are expensive and unless the timber is valuable enough from the commercial, watershed-protection, or aesthetic standpoints to warrant the cost of control measures, it is best to allow Nature to bring the epidemic under control in her own way.

To reach a decision certain data must be obtained. In the first

place, the primary agency responsible for the death of the trees should be determined. If trees are dying because of drought, fire injury, flooding, or other causes, there is obviously little use to dispose of the insects, which may be only the final cause of their death. Nor is it wise to attempt to exterminate native bark beetles present on an area under normal conditions. Only when the natural-control factors have been disturbed and an outbreak threatens should artificial measures be taken.

In the second place, it must be determined whether effective and economical control measures are available. In some cases, because of the habits of the beetles, no satisfactory methods of control have been devised. For instance, the control of the white fir engraver beetles through burning the bark of dying trees is of little value since a large number of these insects may continue to breed in perfectly green trees, causing only local damage. Moreover, the control measures must not be so expensive as to exceed the value of timber that might be saved.

And lastly, it is most important that cooperation be had from all owners in the infested area so that the control campaign can cover all the contiguous infested territory in a single season. Small tracts cannot be successfully cleaned up if neighboring or intermingled tracts are left untreated.

BARK-BEETLE CONTROL PROJECTS

The objective of bark-beetle control is to destroy such a high percentage of the destructive beetles that the aggressive character of an outbreak will be broken and the remaining infestation will be held in check by natural control factors. This involves the treatment of as nearly all of the infested trees within the natural boundaries of an affected area as is feasible within physical limitations; and if migrations threaten from neighboring areas these areas also should be included in the control campaign. Beetle outbreaks, like forest fires, if not promptly taken in hand, are soon apt to increase beyond the practical limitations of artificial control measures.

The Control Unit

The feasibility of a control project will frequently depend on the possibility of limiting the area to a unit that can be covered in a single season with the available manpower. First consideration must be given to the flight habits of the beetles, and the control area should be made large enough to reduce to a minimum the possibility of any large number of beetles flying in from neighboring infested tracts. As far as possible, control units should be bounded by natural barriers, such as high ridges, open valleys, or broad strips of timber of a different type. If these are lacking, then the control area must include all infestation within the flight range of the beetles. This range for practical purposes depends on the intensity of the beetle population in any neighboring area. For instance, in cases where a treated unit is surrounded by scattered infestations of

the western pine beetle, reinfestation in the first year following treatment has been limited to a zone within a mile of the boundaries. On the other hand, some heavily concentrated infestations of the mountain pine beetle have apparently migrated across 30 miles of open country to reinfest control units.

Spotting

The first step in connection with any control project is to locate and mark all infested trees requiring treatment. The success of any control project depends primarily on finding a high percentage of the infested trees. To accomplish this the forest must be thoroughly and systematically searched by men who know an infested tree when they see one. The spotting should be begun several days before the treating and should be kept well ahead of it (fig. 106).

FIGURE 106.—Ponderosa pines spotted for treatment in Black Hills beetle control, Kaibab National Forest, Ariz.

The strip method of spotting is the one best adapted to obtaining a systematic 100-percent coverage of the area and is the one now used on nearly all western bark-beetle projects. According to this method, a compass man and from two to four spotters run strips of uniform width back and forth across the area, mark the infested trees and map their location so that they can be found by the treating crews. With a three-man crew the compass man, who is usually the chief of the party, runs an accurate compass line, paces the distances traveled, records data relative to trees marked for treatment, constructs a map showing their

location, and assists the spotters in the selection of the proper trees for treatment. The two spotters cover strips on the sides of, and parallel to, the course of the compass line, find, blaze, and number the infested trees, and record whatever data are pertinent in regard to them. With a six-man crew there are two spotters on each side of the compass man, and the chief of the party follows behind the crew, working from side to side to assist in the proper marking of the trees and to prevent any from being missed. Regardless of the organization, the chief spotter is always responsible for the character of the work performed by his crew.

The width of the strip and the number of men in the spotting crew are usually adjusted to the timber type, topography, and density of the infestation. In typical ponderosa pine stands a three-man crew, with each spotter covering a five-chain strip, is the standard practice. This width of strip in the open timber stands of this type permits the spotters to visit and closely examine not only the fading trees but all that look suspicious and a high percentage of the green trees as well. On the other hand, in dense lodgepole and white pine stands a one-chain strip is all that a spotter can efficiently cover, since it is necessary to look at the base of every tree, and a six-man crew has been found advantageous in such timber. When large groups of infested trees are encountered, all spotters assist in marking all trees within the group, even though it extends over into the next strip. The spotter who has had the outside course should always be on the inside during the return trip, as he is familiar with the boundaries of his strip.

The trees selected for treatment are marked in different ways, varying from a blaze to a cloth or card tag tacked upon the tree. When tags are used, it is a good plan to blaze and number the tree on the opposite side, as this permits the relocation of trees in case tags are destroyed. The data placed upon tags will vary for each project, depending on what information is desired. Each tree should be numbered regardless of the type of mark used, so that a check can be maintained on the trees treated. After a tree has been treated the tag is removed, and all tags are turned over to the project superintendent at the close of the day's work and checked against the serial numbers of the trees marked within the area.

BARK-BEETLE SUPPRESSION METHODS

Methods of bark-beetle control must take into consideration the varying habits of the insect species, the trees affected, the locality, and the environmental conditions encountered. Methods effective in one area cannot be used in other areas even against the same insect because of differences in local conditions. Methods suitable for the control of an insect in a tree with thin bark cannot be used to control the same species infesting a tree with thick bark. Differences in latitude and altitude have an important bearing on the success of the sun-curing method, and the differences of type and forest cover will often be a determining factor in the selection of a suitable control measure. It is often necessary

to use two or more methods, even on a single project, because of differences in exposure or site conditions, the size of trees infested, or the height of the infestation in the trunk.

Some of the methods that have been of greatest usefulness are described below.

Since most of the destructive bark beetles confine their attacks to a few species of trees, control can be carried out by treating just the affected host trees.

The Fell-Peel-Burn Method

The fell-peel-burn method is one of the oldest for bark-beetle control, yet one which is still used in the suppression of outbreaks of the western pine beetle and related species, the larvae of which burrow into the outer bark and are not exposed when the bark is peeled from the tree.

In this method the infested trees are first felled (fig. 107), either up or down hill but away from new growth or heavy patches of brush—never across the slope of the hill, if this can be avoided, since a broad flame is more difficult to control than a narrow one. Then the bark is peeled from the top half of the fallen trunk for as far as the infestation extends, piled along the sides, and set on fire (fig. 108). The flames creep under the log and scorch the unpeeled bark. If it is desired to dispose of the brush at the same time, the limbs and top are cut off and piled back over the trunk. If this would make too large and dangerous a fire, this material can be left out and burned at a later time or spread on the ground to decay. As a fire precaution, a fire line is constructed by scraping away all the litter and duff down to the mineral soil for a width of about 3 feet and completely encircling the tree. In treating a tree infested with the western pine beetle it is desirable to leave the stump and the duff around it unburned in order to protect the beneficial clerids in their pupal cells, which are usually concentrated around the base of the tree.

The fire should be allowed to consume the infested bark, but should not be so large as to make it difficult to control. In wet weather pitch will have to be supplied to burn the bark sufficiently, while in dry weather all tops, limbs, and even needles will have to be thrown outside the fire line, to keep the fire from becoming dangerously large. In wet weather the burning should be with the wind and uphill, to create enough draft to consume the bark. In dry weather this should never be done, but the burning should be downhill and against the wind, so the fire can be controlled. Burning, if done by experienced men, can be handled without injury to the forest. Ordinarily the fire is not hot enough to burn the logs, and if at all accessible they can be used for lumber if taken out within a year or two.

The Fell-Deck-Burn Method

The fell-deck-burn method is one of the most economical control methods and is particularly useful in the control of bark beetles

FIGURE 107.—Felling bark-beetle infested ponderosa pines is the first step in their treatment.

infesting trees of small diameter (fig. 109) such as small ponderosa pine, lodgepole pine, or western white pine, infested with the mountain pine beetle or Black Hills beetle, especially where large groups of trees are infested. By using tractors or teams even the larger trees can be handled for treatment by this method.

The trees are felled usually in one direction, and then, by using peavies, are hand-rolled into piles, or they are dragged by horses or tractors into openings where they can be bunched into large decks. No peeling is necessary, except occasionally on the outer surfaces of the outer logs. The whole pile is then fired and usually is completely consumed.

This is a very satisfactory method where it can be used and is not only more economical than the fell-peel-burn method but

FIGURE 108.—Trees infested by the western pine beetle are burned after the bark has been partially peeled.

leaves the forest free from the fire hazard of fallen logs and piles of brush. This method also permits the control work to start before the close of the fire season in the fall since the piles can be prepared and the burning can be done at a later date. Since the burning of decked logs throws out terrific heat, the size of the piles should be adjusted to the space available, so that neighboring living trees will not be injured. If this precaution is not taken, the scorched trees may draw in additional infestation and more or less nullify the effects of the control work.

The Oil-Burning Method

Recent control technique has developed an economical method of killing bark beetles in thin-bark trees, such as lodgepole pine, by spraying the bark with fuel oil, firing it, and letting the bark be scorched deeply enough so that the beetles will be killed by the heat. The trees may be either felled and burned or burned in a standing position.

A fuel oil is used that has a high caloric content and burns

FIGURE 109.—Burning in decks is an economical method of treating bark-beetle-infested trees of small diameter.

evenly and without too quick a flash. An explosive oil burns too quickly to give good heat penetration. For burning standing trees a light oil of gravity 32° to 34° Baumé and a flash point of 160° F. has given the best results. For burning trees on the ground ordinary fuel oil with a gravity of 27°+ Baumé and a flash point of 225° F. has been found most satisfactory because of its slower burning, greater heat penetration, and lower cost. In either case from ½ to ¾ gallon is required to burn the average lodgepole pine. The oil is applied with a hand pump through a long nozzle.

With the burning-standing method, the oil is sprayed as high on the bole of the tree as the equipment will permit, about 30 feet at present, and the entire top of the tree is "crowned out" with fire (fig. 110). The treatment is effective only to the height of the burn, and unless the bole is thoroughly scorched as high as to a 6- or 8-inch diameter, which is usually the upper limit of infestation, the tree must be felled and the scorched portion burned with additional oil.

When lodgepole pine bark has been adequately burned to kill the beetles underneath, the bark flakes will curl and show white on the edges. Frequently when this method is used, the spotting and treating are performed at the same time. A pack train carrying the pressure sprayers, oil, and felling tools follows the spotting crew, and infested trees are treated wherever they are found. This method is an economical one, and costs have averaged between 68 cents and $1.05 per tree. This method cannot be used on windy or stormy days, and during dry or windy weather great

FIGURE 110.—Burning a standing lodgepole pine for bark-beetle control.

care must be used to avoid serious conflagrations. It is also limited to trees of moderate height that can be burned as high up as the infestation, and to situations where the fire hazard is not too great.

Lodgepole pine growing in dark woods or in dense thickets of underbrush, where the sun-curing method is not effective, or tall trees that cannot be successfully treated in the standing position can be felled and burned with oil if decking and burning in piles is not feasible. A slow-burning fuel oil is used, and the fire is carried along and confined to the bole of the tree by spraying on oil from a hand pump. Two men follow behind the fireman and

quickly extinguish any fire left on the tree or starting on the ground.

The Peeling Method

The peeling method can be used in the control of those bark beetles that, in the immature stages, work between the bark and the wood and die of exposure when the bark is removed. It is especially applicable to moderately thick-barked trees that are easily peeled. It has been used extensively in the control of the Black Hills beetle in ponderosa pine of the Rocky Mountain region and in the control of the mountain pine beetle in western white pine. There is no immediate fire risk, and it is cheaper than the burning method for the treatment of isolated trees less than 30 inches in diameter. If the bark tends to adhere to the wood, however, peeling is a very slow, tedious process and in the spring will not destroy overwintering adults, new adults, or pupae in the last stages of transformation. It is more expensive than the burning method for the treatment of trees in groups. Moreover, it leaves a mass of slash and crisscrossed logs in the woods, seriously increasing the fire hazard.

In carrying out this method, the infested trees are felled across logs or other felled trees to hold them off the ground, and then all the infested bark is peeled with an ax or barking spud and allowed to drop to the ground, where ants, rodents, and exposure dispose of the immature bark beetles (fig. 111). In some rare

FIGURE 111.—Using spuds to peel western white pines infested with bark beetles.

cases, where all the infestation is within 20 feet of the ground, the barking has been done with long-handled barking spuds without felling the trees. In such cases, of course, the work can be done more cheaply than where felling the trees becomes necessary.

Peeling and Spreading Bark

A modification of the peeling method, in which the bark is spread where it will receive the direct rays of the sun, has been used with fair success in the control of the western pine beetle. It is applicable to the treatment of ponderosa pines infested with broods of this species late in the spring or in the summer in places where burning would be dangerous.

In this method the tree is felled across a log so as to keep a large part of the trunk off the ground, and the bark is peeled and spread out in the open where it will receive the direct rays of the sun. To be effective it is necessary to have summer air temperatures of 85° F. or more, to produce fatal temperatures of 115° to 120° in the bark. The bark must be very carefully spread and must not be left in the shade of other slabs or trees. On north slopes or in canyons it must be carried out to an opening or propped against rocks or trees so that the sun's rays may strike it at an angle of not less than 45°.

It can be readily seen that the method is tedious and expensive and of limited application. Effective temperatures do not always prevail during the control season, especially at high altitudes and on northern exposures. The method also requires a greater attention to detail than can ordinarily be expected from the average workman. Summer control work in which this method is used has not proved very effective, and the method has lost favor in recent years.

The Solar-Heat Method

The solar-heat, or sun-curing, method (*132*) is particularly applicable to the control of bark beetles, other than the engraver beetles or flatheaded borers, that attack thin-barked trees of small diameter, such as lodgepole pines, especially those growing in open stands and in areas where the fell-deck-burn method is objectionable.

In this method trees are felled in a north-and-south direction, parallel to one another and never crisscross, as in the peeling method. They are completely limbed and the brush cleared away so that the logs will receive direct sunlight. After a few day's exposure with air temperatures of 80° F. or more all the bark beetles on the top half of the logs will have been killed. Then the men return and with peavies turn the logs completely over so that the other side will be exposed.

This method has been very effectively used for several years in control of the mountain pine beetle in Crater Lake National Park. It has the advantage of being much cheaper than either the peeling or burning methods; and in crowded stands it avoids scorching adjacent trees, and thus does not set up influences

attractive to the beetles, which would favor reinfestation, as so often happens when the logs are burned. The disadvantages are that considerable slash is left in the woods, and the method cannot be used in the shade of dense stands, on cold north slopes, or in localities where air temperatures during the control season are less than 80° F.

Submerging the Infested Logs

Many years ago A. D. Hopkins advocated submerging infested logs as a means of destroying bark beetles where the infested trees could be cut and placed in a mill pond. Experiments have shown that infested logs must be submerged at least 6 weeks, to destroy the broods of the western pine beetle. In any shorter period the beetle's development is simply retarded. Also, the beetles in the portion of the logs not covered by water are free to emerge and escape. This method has been tried only in an experimental way, but it has possibilities where applicable.

The Trap-Tree Method

A method of bark-beetle control that has been used in Europe with apparent success consists in felling injured, weakened, or suppressed noncommercial trees in accessible locations as attractive bait for bark-beetle broods, and then destroying them after the beetles have entered the bark. The method has been tried on numerous projects and on rather an extensive scale in California and southern Oregon in the control of the western pine beetle, but with little success. Although beetles are attracted to the traps, they fail to protect the standing trees in the vicinity, and frequently the trap tree acts as a source of attraction to bring in bark beetles that kill groups of adjacent standing trees. Moreover, the trap trees have always failed to absorb any large proportion of the beetles in their area, and hence the method has lost favor as an effective or economical control measure. It may, however, prove of value in the control of other species, particularly where the trap logs can be removed and utilized.

Penetrating-Oil Sprays.

Experiments started in California in 1932 have led to the development of a method of control using petroleum oils carrying a toxic agent that, when sprayed on the trunk of infested trees, will penetrate the bark and kill the beetle broods beneath (*140*). Oils of the distillate grade carrying as much naphthalene as could be taken into solution were first used. Then a 6-to-1 mixture of oil and orthodichlorobenzene was found even more penetrating and effective. Since World War II DDT, benzene hexachloride, and chlordane have been substituted as toxic agents with good results. These materials are applied at the rate of about 4 fluid ounces per square foot of bark surface, or until the spray begins to drip. They are most effective when bark is dry and when air tempera-

tures are above 60° F. They are most useful in the treatment of broods in thin-bark trees such as lodgepole and western white pine, and are usually ineffective in such thick bark trees as Jeffrey pine and sugar pine.

These penetrating-oil sprays will give 90 to 100 percent kill of brood when thoroughly applied to trees with thin bark and absorbent bark texture, but it is often difficult to get thorough coverage and uniform penetration (because of individual tree bark characteristics), even when applied by careful and fully experienced workmen. The use of penetrating-oil sprays has become standard practice for controlling mountain pine beetle broods in lodgepole pine in parts of the Rocky Mountain region, and this method has also been used with good results in the control of the Black Hills beetle in small ponderosa pines in South Dakota, and for controlling the Engelmann spruce beetle in Colorado.

Tree Injection

Injecting chemicals into the sapstream of trees in order to kill infesting insects has intrigued experimenters for more than 100 years. Recently it has been tried in the control of various bark beetles, particularly the mountain pine beetle in western white pine stands (*12*), with good results under certain conditions. Recently killed trees are girdled at the base by a saw-kerf which penetrates through the sapwood. Then a rubberish cloth collar is attached and a solution of powdered copper sulfate introduced in the collar. This is taken up by the tree and the poison distributed through the trunk causing mortality to bark beetles in the inner bark. The method has limitations in that it must be applied within 90 days from the first bark-beetle attack while the tree is still functioning; distribution of the chemical is affected by blue-stain fungus, density of wood, and other factors; and the difficulty of applying collars limits the method to rather small-scale projects where the labor factor is not too important.

Introduction of wood-preservative chemicals into the sapstream of living trees is a highly effective method of rendering wood, particularly rustic work, fence posts, and small poles, resistant to insect and fungus attack. Many different wood-preservative chemicals can be used, but the most satisfactory are chromated zinc chloride, zinc chloride, and copper sulfate, used at concentrations of ½ to ¾ pound per cubic foot of sapwood to be treated.

Logging

Where the infestations are in accessible tracts of valuable timber, the cutting and salvage of the infested trees through logging operations is an effective and economical method of control. This method was first advocated by Hopkins—for the control of *Dendroctonus* beetles. He proposed that the infested logs be removed from 20 to 50 miles from the forest so that the beetles emerging from them would find no trees to attack. Often this method has been followed unwittingly by logging operators who

have cut infested trees and sent them to distant mills or burned the slabs; and this, together with the removal of beetles in recently felled green logs, explains the absence of insect-killed trees around many going logging operations. Of late years this method has come more and more into favor with the opening up of forest tracts and the development of truck logging, which has made possible the removal of scattered infested trees at comparatively low costs (*84, 89*).

This method serves the dual purpose of controlling the bark beetles and salvaging timber that otherwise would be completely worthless within a short time. Where the method can be used it is economical and sometimes can be carried out with a small immediate profit from the operation in addition to suppressing the beetle outbreak. Even if the logging operation is carried out at a loss of from $1 to $2 per thousand board feet of timber, it is better than spending $3 or $4 per thousand feet to fell the trees and burn them or leave them in the woods, as is the case with the usual control operations. The reduction of infestation will be the same by either method.

In inaccessible areas the method cannot be applied except at a cost in excess of that of the ordinary control methods, and of course cannot be used in the control of bark beetles attacking unmerchantable species of trees whose chief value lies in the protection of watersheds or as a forest cover in parks and recreational areas. Moreover, bark beetles introduce blue stains which discolor the sapwood before there is any possibiilty of salvage, and thus reduce the value of the material. In ponderosa pine areas it rarely pays to salvage tops or trees less than 22 inches in diameter, and such unmerchantable material must be burned to complete the control operation. Because of immediate blue staining, the value of the logs taken out of the woods is reduced approximately 50 percent below that of green logs, so returns from the operation must be computed on that basis. If the method is to be effective, the beetles on an entire unit must be destroyed in a single season, which means that the logging operation must frequently be extended over a very large area. This is often difficult, so logging must be supplemented in many cases by the ordinary control methods.

MAINTENANCE CONTROL

One season's treatment of an area will rarely be sufficient to bring an outbreak under control. Even with the most careful spotting and treatment some infestation will be missed that will give rise to new infestation the following year. A follow-up program, or maintenance control, is therefore necessary until the normal balance is restored and the bark beetles reduced to an endemic status.

With infestations of the mountain pine beetle, unless migrations occur, a 75-percent reduction is usually obtained following the first season's work, and one or two seasons of maintenance work will usually bring the epidemic under complete control. In western pine beetle control, reductions of more than 50 percent

are rarely obtained in one season, and the work has to be repeated for several seasons, until the resistance of the stand has improved through removal of beetle-susceptible trees or until the trees are better able to resist attacks. In fact, during long periods of drought and lowered tree resistance, almost continuous work may be necessary to hold the beetle population down to reasonable limits.

In this work special consideration must be given to the natural-control factors and an effort made to favor their effectiveness while reducing the population of the destructive species. The avoidance of burning around stumps where predators congregate, the saving of certain infested trees to permit multiplication of the beneficial parasitic insects present, and the improvement of stand resistance are some of the ways in which natural control may be encouraged (pp. 211, 215, 218, 220).

CONTROL COSTS AND PROBABLE RESULTS

The cost of control work varies with the size and type of timber, the method of treatment, the intensity of the infestation, the roughness of the terrain, the accessibility of the area, the current cost of labor, and so many other factors that it is impossible to give any specific costs that might apply to a given situation. Some idea of the approximate cost of the work, however, may be obtained from experience gained during the decade from 1921 to 1930.

In the ponderosa pine region of California, Oregon, and Washington the control of the western pine beetle cost on an average about $4 per treated tree, with the cost dropping as low as $1.75 per tree. In the control of the Black Hills beetle in ponderosa pine of the Rocky Mountain region the cost per tree averaged about $1.50 with some costs as low as 75 cents per tree.

The control of the mountain pine beetle in lodgepole pine forests, where either the solar-heat method or the fell-deck-burn method was used, cost on the average from 50 cents to $1 per treated tree, depending largely on the intensity of the infestation. Under similar conditions the solar-heat method is the cheaper of the two.

The control of mountain pine beetle infestations in western white pine cost about $4.50 per tree, and in sugar pine, because of its very large size, the costs sometimes amounted to as much as $16 per tree.

For the treatment of a few scattered trees around summer homes or in inaccessible areas the costs will run higher than on large-scale projects.

Bark-beetle control work has been in progress in western forests since 1911. The results of this work for the first 20 years were summarized in 1931 (*39*). Since then much further progress has been made in the development of materials and techniques of application.

Wherever bark beetles have been primarily responsible for the death of trees, the application of control measures has resulted in reducing the infestation or in restoring the natural balance

so as to bring the outbreak under control. With such aggressive tree-killing species as the mountain pine beetle and the Black Hills beetle, control work has been very effective in quickly suppressing outbreaks wherever a high percentage of the infested territory could be covered in a single season and the results were not nullified by migrations from distant areas. Western pine beetle epidemics have so frequently been partly dependent on a weakened condition of the host trees that the results from control have not been so clear-cut. Infestations have been reduced, but unless the work is continued or conditions bring about improved tree resistance, the reductions brought about by control efforts are difficult to maintain.

At best, remedial bark-beetle control is only a temporary expedient, or a method of suppressing outbreaks that have been brought about through some interruption, disturbance, or failure of the biological balance. The only permanent protection is through the management of forest properties so as to maintain the natural balance, or if this is broken by forces beyond man's control, to be able to salvage the killed timber quickly enough to prevent excessive loss.

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INDEX OF HOST TREES

NOTE.—The insects are grouped according to the part of the tree where they are usually found. Sometimes insects working under the bark of the trunk are also found in limbs and twigs or entering the wood. Some bark borers may, in the adult stage, even feed on the needles. Insects known to kill trees are preceded by an asterisk.

GENERAL INDEX

[Exclusive of host references listed on pp. - . Page numbers in italics denote principal references.]

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